LABORATORY EXERCISES IN GENERAL ZOÖLOGY

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BY e

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W. P. I

PREFATORY NOTE

THE following outline of work in practical zoölogy is intended to be flexible both in material and in order of presentation. Material may be added or eliminated and the order of presentation may be changed to suit the conditions of the school or the views of the instructor. As it stands, it represents the author's idea of the general nature and extent of a course in practical zoölogy, that, when supplemented by the text, will constitute a knowledge of animal life that should occupy its proportionate share in the education of a well-rounded person in the ordinary pursuits of life. The author has attempted to combine Huxley's "verification" method with Agassiz's "investigation" method in such proportions as to maintain interest, cultivate scientific habits of thought, and impart lasting information.

Some do not think it best to begin with the microscope, but the author's experience indicates that high school pupils, sufficiently advanced to take a course in zoölogy equivalent to the one outlined here, learn to use the microscope as easily in the early part of the course as in its later stages. Pupils of this age are so interested and enthusiastic over the wonders of microscopic life that they are eager to learn to use the microscope and, with few exceptions, handle the instrument with skill and fine care, often verging on solicitude.

Also, some teachers prefer to begin the subject of zoölogy with the study of one of the higher animals; for

example, a grasshopper, crayfish, or bird. To meet this view, each of the laboratory exercises practically stands as a unit, and any one of the above animals may be used to introduce the subject if desired; but the exercise on the grasshopper is designed especially for introductory work. Moreover, there is sufficient unity in the treatment in the text of the groups of animals represented by the foregoing examples to make such a method perfectly feasible.

GLENN W. HERRICK.

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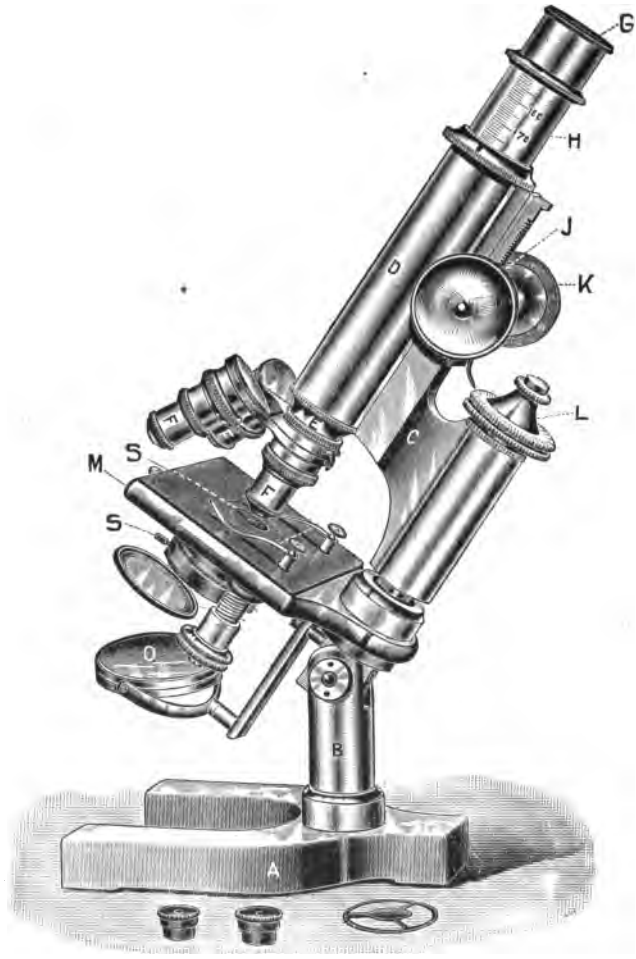

FIG. 1.—Microscope; G, eyepiece; J, coarse adjustment; K, milled wheel; L, fine adjustment; H, draw tube; F, objective; M, stage; O, mirror; B, pillar; D, tube, or body; S, diaphragm.

LABORATORY EXERCISES IN ZOÖLOGY

PRELIMINARY EXERCISES

I. — Use of the Microscope

Materials. — A compound microscope fitted with $\frac{2}{3}$ and $\frac{1}{6}$ inch objectives, glass slides for mounting objects, wing of a house fly, cover glasses; objects for mounting, such as cotton fibers, hairs, blood cell, pond scums, etc.

Directions. — (The author has found it advantageous to set a microscope in a conspicuous position and to have the class make a diagrammatic drawing of it from a side view, afterward, carefully naming all the parts.)

A. Parts of the Microscope. With the aid of Figure 1 locate on the microscope the following parts: draw tube, stage, mirror, pillar, large and small milled wheels, eyepiece, objectives.

B. Coarse Adjustment. Place the microscope on the table, with the pillar next to the face and with the stage pointing away. Take hold of the large milled wheel on the right side, and turn it toward the operator. What happens to the tube? As the tube may be rapidly lowered and raised by this wheel, it is called the *coarse adjustment.*

C. Fine Adjustment. Place a glass slide on the stage and lower the $\frac{2}{3}$ objective until it is about $\frac{1}{4}$ of an inch from the slip. Put the head down until the eye is on a level with the stage. Sight across the slide, and with the hand

turn the milled wheel on top of the pillar to the right. What happens to the objective? Does it move quickly or slowly? The wheel on top of the pillar is called the *fine adjustment.* Why?

D. TAKING OUT AND PUTTING IN THE EYEPIECE. Elevate the tube so that the objective is an inch or more from the stage. Grasp the tube with the left hand, and with the other hand pull out the eyepiece by taking hold of the milled ring at the top. Never put the fingers on the lenses, but use an old, soft handkerchief for cleaning them. To put the eyepiece in place, hold the tube as before, else the objective may be forced against the stage and be broken.

E. TAKING OFF AND PUTTING ON THE OBJECTIVE.[1] To remove the objective, always elevate the tube. Grasp the objective lightly at the milled ring on its lower end, with the thumb and forefinger of the left hand, and with the thumb and forefinger of the right hand unscrew the objective at the milled ring at its upper end. In this way the objective will not be dropped and broken. To replace the objective, reverse the operation. Practice this until it can be done with ease and facility.

F. LIGHTING THE OBJECT WITH THE MIRROR. Place the wing of a house fly in a drop of water in the middle of the glass slide. Carefully drop a thin cover glass on top of the wing. Elevate the tube and place the object on the stage. Then with the eye at the eyepiece and looking through the tube, turn the mirror in different positions. What happens? What is the mirror for? Examine the mirror and note its surfaces. How do its two surfaces differ? What is the difference in effect when lighting the

[1] If microscopes with double nosepieces are used, this work is not necessary.

fly's wing with the concave and convex sides of the mirror? Which side throws more light on the object?

G. DIAPHRAGM. Note the circular, revolving disk beneath the stage with its various sized openings. This disk is called the diaphragm. Try each opening successively, and note the effect on the wing. Which opening is best to use on a dark day? Which is best to use on a sunny day? It is best for the eye not to use too bright light.

H. FOCUSING WITH THE DIFFERENT OBJECTIVES. Using a $\frac{2}{3}$ objective, run the tube down until the bottom of the objective is about $\frac{1}{2}$ inch from the object. With the eye at the eyepiece very slowly lower the tube until the wing comes plainly into view. The object is then said to be in focus. If in lowering the tube the wing is not seen very soon, look at the end of the objective, and note how close it is to the object. If it is nearer than $\frac{1}{4}$ of an inch, elevate the tube and try again. Watch closely and never run the objective into the object. A $\frac{2}{3}$ objective will stand about $\frac{1}{4}$ of an inch from the object when in focus. A $\frac{1}{6}$ will allow a piece of ordinary paper between it and the object.

Using the $\frac{1}{6}$ objective, run the tube down until the end *almost* touches the object. Then, with the eye at the eyepiece, run the tube up and down with the fine adjustment until the wing comes into focus. *Always use the fine adjustment with the $\frac{1}{6}$ objective.*

Mount various objects on slides in water under cover glasses. Cotton fibers, hairs, blood cells, pond scums, etc., will serve for this purpose. Focus with both objectives on these objects again and again, until the operation of lighting and focusing is thoroughly mastered.

Reference Book.—The Microscope and Microscopical Methods by Simon Henry Gage, Comstock Pub. Co., Ithaca, N.Y., $1.50.

II. — The Functions of Organs

Materials. — A live locust, a frog, a chicken leg, a duck's leg, wing of a sparrow, fore legs of a rabbit, a butterfly.

Directions. — (Procure several live locusts and allow them to go free in the room or in a large cage.)

A. Study of a Living Locust. Study the movements of a live locust. What use is made of the front legs? What are the hind legs used for? Note carefully this difference in function between the fore legs and the hind legs. The front legs are of most service in walking, while the hind legs are used in leaping. Now note the difference in size and structure between these pairs of legs. This comparison shows us that a difference in the functions of organs may be accompanied by a difference in the structure of those organs.

B. Now compare the hind legs of a locust with the hind legs of a frog. The frog's hind legs are also used as leaping organs. Is the relation of size and structure between the front legs and hind legs of these animals similar? This comparison shows us that a similarity of function may be accompanied by a similarity of structure.

C. The frog's leg is also used for swimming. What structure between the toes fits the leg for a swimming organ? Is such a structure found on the locust's foot? Does the locust swim? It would seem then, from this study of the frog's leg, that an organ is structurally fitted for the function it has to perform.

D. Study the leg of a chicken and of a duck. How do they differ in function? How do they differ in structure? Are both legs especially suited to the work they are called upon to perform?

Study the wings of a sparrow, and compare their structure and their functions with the structure and functions of the fore legs of a rabbit. The wings of a sparrow and the fore legs of a rabbit are homologous organs.

Compare the mouth parts of a locust with those of a butterfly. The locust chews its food, while the butterfly sucks its food (nectar) from flowers. Note the striking adaptation of structure to meet these functions.

This work may be carried further, but, as it is emphasized throughout all the practical work, perhaps further study here will not be necessary.

III. — The Classification of Animals

Materials. — Several specimens of tobacco worm and tomato worm moths, members of the hawk-moth family, beetles, butterflies, flies, bugs, etc.

Directions. — During the summer collect several specimens of the tobacco and tomato worm moths. If the moths [1] cannot be obtained readily, find the larvæ and rear them in cages (see Appendix). By rearing the moths more perfect specimens may be obtained. Also collect other members of the Hawk-moth family, the Pandora Sphinx,[2] the Lesser Vine Sphinx,[2] etc., and some beetles, butterflies, flies, and bugs. If it is more convenient to obtain butterflies, collect different species of the cabbage butterflies.[3]

A. Compare any two individuals of the tomato moths. Note the shape of the fore and the hind wings. Note the colors of the wings of each moth, and compare. Note the

[1] See the "Moth Book" by W. J. Holland, Plate IV, Figs. 1 and 2.

[2] *Ibid.*, Plate III, Figs. 6 and 2.

[3] See "How to Know the Butterflies" by Comstock, Plates XIII and XIV.

markings on the abdomens, and compare. Note the size of the wings, and compare. As a result of these comparisons, note that the wings and abdomens of these moths are alike in size, shape, and color. Evidently, they are of the *same kind*, — simply two individuals of the same kind of insect. There are many other individual tomato moths in the world, all of which are of the *same kind* and are known as a *species*.

Examine two of the tobacco moths in the same way, and compare. Here, again, we find several individuals so nearly alike that we consider them the same kind, or species.

B. Now compare a tobacco moth and a tomato moth. They are not alike and are not of the same species, for they differ in the colors of the wings and the markings of the abdomens. Yet they have similar antennæ, wings of nearly the same shape, and abdomens alike in size and shape. Clearly, they are very closely related species and may be assembled in one group. Such a group, composed of several very closely related species, is known as a *genus*.

A genus is given a single name taken from the Greek or the Latin language. The genus containing the tomato and tobacco moths is known as *Protoparce*. There are other moths that belong to this genus, and they are all known under the name of *Protoparce*. But, since the tobacco and tomato moths are different species, they must have different names in order that we may be able to designate them. Therefore, the tomato moth is called *Protoparce sexta* and the tobacco moth is called *Protoparce quinquemaculatus*. In these names the word *Protoparce* indicates the genus to which these moths belong, while the words *sexta* and *quinquemaculatus* indicate the respective species to which they belong. That is, the scientific name of every animal

consists of two words, the first of which is the name of the genus to which it belongs, while the second is the name of the species to which the animal belongs.

C. Examine the Pandora Sphinx and the Lesser Vine Sphinx, — other hawk moths will do quite as well. Note that these are quite different from the tobacco and tomato moths in the colors and markings of the wings and abdomens. Indeed, the Pandora and Lesser Vine Sphinxes are so unlike the tobacco and tomato moths that the former are placed in an entirely different genus, namely, *Pholus.* Yet all of these moths have a general similarity. They all have long, narrow, graceful front wings and small hind wings. Their abdomens are comparatively large, and they fly at twilight or at night. They all have long probosces with which they suck the nectar from the flowers of honeysuckles and other plants. Therefore, these two genera of moths, together with other genera of like moths, constitute a *family* known as the hawk-moth family (Sphingidæ).

D. Compare the hawk moths with other moths and with butterflies. Note that when handled a fine dust-like substance is rubbed from the wings and is left clinging to the fingers. Examine this dust under the microscope. It will be seen to consist of minute scales of various forms. With very few exceptions, the wings of all moths and butterflies are clothed with fine scales, and are consequently similar in this respect. On account of this similarity butterflies and moths are all assembled together in a large group known as an *order* (Lepidoptera).

E. To carry our classification further, many more insects of different kinds must be compared. It will be found in such comparison that they all have six legs and that their bodies consist of three great divisions, — head, thorax, and

abdomen. Therefore, all insects fall into one great group known as a *class* (Hexapoda, or Insecta). To go further and compare insects with crayfish, lobsters, spiders, sow bugs, etc., we should find that all of these animals have segmented legs and segmented bodies. Therefore, on account of these similarities, they are all assembled in one great group known as a *branch* (Arthropoda).

If time is available, no better scheme of improving it could be devised than by devoting a few exercises to the classifying of a few common insects. For example, collect several specimens of our common insects representing the orders of locusts, bugs, flies, beetles, bees, and butterflies. Make a careful study of the leading characteristics — the similarities and differences — of the individuals until the insects of like characteristics can be grouped by themselves. Name the groups (orders). Select some cabbage butterflies and some swallow-tail butterflies. Note the differences and similarities and separate them into groups containing like individuals. Name the groups (genera). Finally, select some individual swallow-tail butterflies and separate them into species.

IV. — Plant Cells

Materials. — Pond scums, glass jars, melon vine, moss, glass slides, cover glasses, compound microscope.

Directions. — Collect some pond scums from different sources and keep them in glass jars, changing the water now and then to prevent it from becoming too stagnant. Spirogyra is a very common species of pond scum. It may be recognized from the green, spiral bands inside the long, slender threads.

Find a melon vine, or, some time before it is needed, plant some seeds of this vegetable in a pot and allow the plants to grow a foot or more in length. Collect a quantity of a moss that has thin, flat leaves, and keep it in a moist jar until wanted.

A. Mount a bit of the pond scum in water on a glass slide and cover with a cover glass. Examine with the low power ($\frac{2}{3}$) objective.

What is the color of the plant? Of what does the plant, as a whole, consist? What are the structural units of a single thread? What is the shape of each cell? Note the spiral band in each cell. Are the cells longer than they are wide?

Make drawings showing the threads and the cells. Make notes on the color, appearance, and habitat of the plant.

B. Mount a leaf of the moss. Note the shape of the leaf and the midrib. Note that the leaf is made up of cells. Note that the cells are of various sizes and shapes. What is contained within them? Do they possess walls?

Make a drawing of the whole leaf and then of a half dozen cells much enlarged.

C. Examine the melon vine, and note the fuzzy appearance of the stems. What causes it? Carefully scrape off some of the hairs with a sharp scalpel or knife and mount them on a glass slide in water. Examine with the low-power objective, and note the shape and structure of each hair. What is the shape of each cell? Note that the cells are joined end to end.

Make a drawing of a hair showing its structure.

With the high-power objective watch closely for some length of time a single cell. Is the wall of the cell opaque or transparent? What is inside of the cell? Note a light, circular spot, the nucleus, usually at one side of the

cell. Look carefully for the fine threads of protoplasm running from the nucleus to different parts of the cell. Is there any movement in these threads? (N.B. — It will take close, careful observation to determine this point.)

Make a drawing showing the cell and its nucleus and streams of protoplasm.

In conclusion it will be noted that all the plant cells examined possess walls. This is true of most plant cells, although there are exceptions. Note that each cell contained protoplasm and a nucleus, although these structures could not be made out easily, in the cells of the pond scum and moss leaf. Finally, note that the protoplasm had the power of movement.

V. — Animal Cells

Materials. — Scalpel or ivory knife, glass slides and cover glasses, compound microscope; amœbæ; one per cent acetic acid; paramecia, peach-tree gum or cotton fiber; vorticellæ.

Directions. — (Amœbæ are sometimes difficult to obtain in sufficient numbers for a whole class; but epithelial cells may be obtained, simply by scraping the inside of the cheeks with a sterilized scalpel, or ivory knife.)

A. An Epithelial Cell. Place the substance obtained from the mouth upon a slide, cover with cover glass, and examine with low-power objective. Are there any cells in the material? What are the shapes of the cells? Note the nucleus in any one. Note the granular protoplasm and the wall bounding the cell. Draw some of these cells.

B. Amœba. (If possible, obtain a few amœbæ. They live in the ooze and slime on leaves, sticks, etc., in standing water. Collect this material from different places, and allow it to stand

in shallow dishes for several weeks, being careful not to allow all the water to evaporate. Cultures of these materials should be started in the spring for work in the autumn.)

Mount on slides bits of the material from the different dishes and search carefully for opalescent or transparent spots that are constantly changing position. This is often a little tedious, and needs to be persisted in to be successful.

Having found the animal, note its movements. Does it always move in one direction? Write a description of the various movements of the amœba. Judging from the directions in which the amœba moves, does it have an anterior and posterior end? Of what is the body of the amœba composed? Is the body clear or granular? Find an oval, transparent organ, the *nucleus*, within the body mass. Is the amœba composed of one or more than one cell? Is the body inclosed by walls? What, then, is the great difference between this animal cell and the plant cells already examined? From what part of the body are the streams of protoplasm sent out? Find the particles of food surrounded by water. These are known as the *food vacuoles*. How does an amœba obtain its food? See text, page 15. How does it breathe? Note the *contractile vacuole*. This is a globule of clear liquid which forms near the outside of the animal and discharges into the surrounding water. How often does it pulsate?

The contractile vacuole is an organ of excretion by which the waste products are thrown out of the body.

To see the nucleus in this animal and the following one-celled forms, they should be killed by a one per cent solution of acetic acid, when the nucleus will become visible in the dead bodies.

Note the clear layer of protoplasm around the outside of the body. This is the *ectoplasm*. The granular inner protoplasm is called the *endoplasm*. Note the flow of granules along the *pseudopodia*. If the animal comes in contact with a particle of sand, note its behavior. Does the amœba possess sensation, judging from its action when touching the sand?

Make drawings of the amœba in two different positions.

C. PARAMECIUM. (These animals may be obtained by placing a handful of hay in a jar of pond water together with some decaying sticks and leaves. Place the jar in a warm place, and in a few weeks there should be an abundance of paramecia just beneath the scum which will appear on top of the water.)

Mount some of the material on a slide in water. Note the paramecia moving rapidly in the field. If they move too rapidly for study, they may be entangled in fibers of cotton placed beneath the cover glass. A thin solution of peach-tree gum, made by melting the gum in water, makes a very good mounting medium. The gum solution will retard their movements sufficiently for study.

Note the shape of the body. Note that the body is inclosed by a very thin, transparent cuticle. Did the amœba have such a cuticle? Is the body divided into compartments by cross partitions? Is this a one-celled animal? Note that the body is covered by rows of cilia. If the paramecium is killed by a one per cent solution of acetic acid, the cilia will show more plainly. Where are the longest cilia?

Note on one side of the body a groove, — the *oral groove*. From this a throat leads into the interior of the body. The mouth is at the bottom of this throat. The nucleus may be seen in the dead animal.

Mount some more living ones and observe the movements

of the animals. Do they move as though they had anterior and posterior ends? Do they move in straight lines? In moving, is the same side of the body kept uppermost all the time? It will be noted that the body revolves now and then. The paramecium is unsymmetrical, and if it did not revolve it would travel in a circle.

Does the paramecium seem more complex than the amœba?

Make a drawing showing all the structures noted above.

D. VORTICELLA. (Ordinarily this may be obtained by gathering leaves, sticks, and pond scum from fresh-water ponds and pools and allowing them to stand for a few days in a warm place. Very often they may be found in the material at once. Sometimes colonies of certain species may be seen with the naked eye, as a whitish mold, along the surface of a leaf or stick. Jar the dish and note the sudden contraction of the whole mass.)

Mount some of the vorticellæ. Note the sudden disappearance of one and then its slow reappearance into the field of the microscope. Is the animal attached to anything? If so, how? Note the transparent sheath of this stem and the solid rod within. What happens to the stem when the animal contracts? Note the action of the stem when the animal pushes out into the field again. When the vorticella contracts what shape does the body assume? What is the shape of the body when the animal is fully expanded? What is seen around the edge of the inverted bell-like body? Do these cilia move? Note the deep *oral groove,* bordered by cilia that extends from the edge of the bell into the body. The *mouth* is borne at the lower end of this groove. Note the currents of water that are being directed toward the oral groove by the cilia. What are these currents for?

Note that the body is inclosed by a thin cuticle like that of the paramecium. Note the crescent-shaped *nucleus*.

Make written descriptions of the movements of the vorticella.

Make a drawing of the body.

E. Topics for Further Study. Sum up the characteristics of all these animals. Write out a comparison of the manner in which the different forms obtain and digest food, move, breathe, and reproduce. Define a living animal cell from your observation of these forms.

STUDIES OF ANIMAL TYPES

VI. — A Simple Marine Sponge (Grantia)

Materials. — Specimens of Grantia preserved in formalin or alcohol, watch glasses, scalpels or razors, caustic soda, test tubes, glass slides, cover glasses, compound microscope.

These sponges occur in the sea along the Atlantic and Pacific coasts, and may be obtained from dealers in zoölogical specimens.

Directions. — (Place the individual sponges in water in watch glasses or small shallow dishes.)

A. External Features. Note the shape of the body. Note the collar of long, transparent spicules around the free end of the sponge. In nature the other end is attached to some object in the sea. Note the smaller sponges attached to the bases of larger ones in some cases. These are produced by the process of budding.

Note that the collar of long spicules surround an opening, the osculum, or mouth. This osculum is also called the exhalent opening, because the water flows out of the body through it. Observe the small spicules covering the whole body. Can the openings of minute pores be seen on the sides of the body?

Make a drawing of the animal.

B. Internal Features. With a very sharp scalpel or old razor cut a dry specimen in halves, lengthwise. Is the body solid or hollow? With the low power objective examine the sides of the body cavity and note the minute openings in them everywhere. These are the openings of

a system of radial canals that run nearly through the walls of the body, but end blindly just before reaching the outside. Make a very thin, longitudinal section with a razor and examine with the microscope. Note these radial canals and also a set of parallel canals that begin at the outside of the body and end blindly just before reaching the body cavity. The radial and inhalent canals communicate with each other by fine openings through their adjoining walls.

Draw one half of the sponge (enlarged) to show the body cavity and the radial canals.

Make a very thin cross section of a dry sponge. Note the round opening in the center of the section. What is this? Note the two sets of canals mentioned above. Note the arrangement of the spicules in the walls of these canals.

Boil a small piece of the sponge for a short time in caustic soda, in a test tube. The spicules will separate from the tissues and fall to the bottom. Mount some of them on a slide. At least two kinds will be found, the tri-radiate and the needle-shaped. The tri-radiate spicules, will, for the most part, have the prongs running off at equal angles of 120° from each other. Occasionally some will be found in which the prongs form right angles. In this case the spicules are T-shaped.

Make drawings of the different kinds of spicules.

C. Topics for Further Study. Sum up the leading characteristics of a simple sponge. To what branch does it belong? Compare it with an amœba. Discuss its manner of obtaining food. How does it reproduce? How does it respire? Where is it found? Note that it is a multicellular animal, but stands next to the Protozoa.

VII. — The Fresh-water Hydra

Materials. — Hydras in glass jars, pipette, watch glasses, hand lens or low-power objective, glass slides and cover glasses, compound microscope.

Directions. — (The fresh-water hydra is found nearly everywhere in ponds, ditches, and pools, attached to sticks, leaves, etc. It is often found among duck weed. We have often found the green hydra in ditches among spirogyra. Collect some of these materials and place them in glass jars in a warm room some days before needed. The hydras, if present, will be seen attached to the sides of the jar.)

A. Study of Living Hydra. Observe them in the jar. Are they free or attached? How do they differ from paramecia in regard to their movements? What is the shape of the body? What is on the free end of the body? How many of these tentacles are there? Do they have the power of movement? Tap the jar and note the effect.

What is the color of the hydra? (There are two species, the green hydra and the brown hydra.) Is the free end of the hydra held up or down? If neither, how is it held? Note the gentle swaying of the body and tentacles. When the hydra contracts, what shape does the body assume? Also note the appearance of the tentacles when they contract.

B. External Features. By means of a pipette or glass tube, remove one of the hydras and place it in water in a watch glass.

With a hand lens or low objective, note the long, cylindrical body. Note the tentacles and their number. Note the irregularities or small knobs all over the distal end of the body and the tentacles. Tap the glass and note effect.

Get one in position to note the mouth between the bases of the tentacles. The attached end of the body is called

the *foot*. It is an adhesive disk which gives out a sticky secretion for attachment to submerged objects.

Make a drawing of the body to show its shape.

C. STRUCTURE OF THE BODY. Mount the living hydra in a drop of water beneath a cover glass, with a hair or small strip of paper on either side, to prevent the cover glass from crushing it.

Examine with both objectives. Note that the body is simply a tube. The large hollow running lengthwise of the body is the body cavity (*gastrovascular* cavity). This is the digestive and circulatory cavity in one, for the hydra has no alimentary canal and blood vessels. The food, which consists of small crustaceans and other minute animals, is passed into the mouth by the tentacles. The cells lining the body cavity secrete a digestive fluid which acts upon the food, preparing it for assimilation. The flagella, which project from the cells lining the body cavity, create currents that carry the food to all parts of the body.

With the high objective note the two layers in the body walls. There is an outer layer, the *ectoderm*, and an inner layer, the *endoderm*. Compare the shape of the cells of the ectoderm and of the endoderm. How do they differ? If the hydra is a green one, note the green bodies (Algal cells) embedded among the cells of the endoderm.

Note the prominent, rounded, oval cells in the ectoderm of the tentacles and the distal portion of the body. These are the *stinging thread* cells. If necessary, crush a tentacle, in order to get a good view of one of these cells. Note the fine thread coiled within each cell.

Draw a stinging thread cell.

Make a diagrammatic drawing of the body showing its general structure.

Note that some individuals have small hydras attached to the sides of their bodies. Hydras reproduce by budding (see text, page 49).

D. TOPICS FOR FURTHER STUDY. Give the leading characteristics of the hydra. Discuss its manner of obtaining and digesting food, its reproduction, and movement. Compare it with a sea anemone, coral polyp, and jellyfish. Fix firmly in mind the position of the hydra and its relatives in the animal kingdom.

VIII. — A CAMPANULARIAN HYDROID

Materials. — Campanularian hydroid, glass slides, cover glasses, compound microscope.

Directions. — (This cœlenterate lives in the sea attached to rocks, seaweed, etc., and may be obtained from any of the dealers mentioned on page 110.)

Mount some of it in water on a glass slide. Note with the naked eye its resemblance to a plant. What color is it? What is the general form of the animal? The stem with its branches is called the *hydrocaulus*. Note the horizontal, threadlike stems running along the surface of the seaweed to which the animal is attached. Note that the hydrocaulus is attached to these stems, which are called the *hydrorhiza*. What surrounds all the stems and branches? This transparent sheath is called the *perisarc*. Inside the perisarc note the dark rod, or axis. This is the *cœnosarc*. Note that it runs into all the branches and connects with the zoöids.

It will be noted that there are two kinds of zoöids, the *nutritive* and the *reproductive*. The nutritive are situated at the ends of the side branches. Note that the perisarc

is expanded at the ends of the branches into cuplike forms in which the nutritive zoöids sit. Are all the nutritive zoöids expanded? They can contract and withdraw into the cuplike ends of the branches, and, no doubt, some will be found in those positions. Note the immature zoöids at the ends of some of the branches.

Look along the hydrorhiza, near the base of the hydrocaulus, and in the axils of the side branches, for smooth, club-shaped bodies. Note that they resemble a large capsule and contain many globular bodies. These are the *reproductive zoöids*. They contain the medusæ buds. After a time the capsule (gonotheca) breaks open, and the medusa buds escape, and develop into umbrella-shaped medusæ, or, as they are often called, jellyfish. After swimming about for a time the medusæ produce eggs that in turn develop into the plantlike structure which we are now studying.

Make a drawing showing all the points mentioned.

IX. — The Starfish

Materials. — Specimens of starfish preserved in formalin or alcohol, also some living specimens, if possible, dissecting instruments, fine-pointed syringe, carmine, brittle stars and sea urchins for comparison.

Directions. — (Those living inland can obtain starfish from a dealer in supplies of that kind. See page 110. Such specimens will be preserved in alcohol or formalin.)

A. External Features. Note the color of the body above. In one common species the bluish ones are the females while the lighter colored ones are the males. Note that the body and rays are more or less flexible, yet hard.

The body is composed of calcareous plates, or ossicles, joined to one another by a soft, flexible membrane. Note the many harsh spines all over the body, both above and below. *This array of spines is a characteristic of the branch, Echinodermata,* although it is not constant. Note that the body consists of a central disk from which radiate five arms. This *radial symmetry is universal* throughout the Echinodermata. Are the spines ever in rows on the arms? What is the shape of each arm? Does every specimen have five arms? If not, find a possible explanation. The lower surface of the body upon which the mouth is situated is called the *oral surface.* The upper surface is called the *aboral surface, i.e.* the surface away from the mouth.

Note on the aboral surface, between the bases of two arms, a small, circular plate, marked with undulating lines. This is the *madreporite.* It is the cover to the stone canal. Find the small, soft, filiform processes that project on the aboral surface between the calcareous plates. These are the *branchiæ.*

Make a drawing of the aboral surface, showing as many of these structures as possible.

On the oral surface, in the center, note the mouth. Note the spines projecting over it. Cut these away and find the opening of the mouth. Is it circular or pentagonal? Note that a groove runs along the middle of each arm. These are the *ambulacral grooves.* Each one of these grooves is bordered by two or three rows of movable calcareous spines.

Note on the sides of each groove two rows of soft white projections, the *tube feet.* The areas occupied by the tube feet are the *ambulacral areas.*

Make a drawing showing these structures.

B. Internal Features. Turn the animal on the oral side and cut off the tip of one ray. Note that the space inside is taken up by two soft brown organs. With a pair of scissors, cut carefully along each side of the arm to the disk. Lift up the aboral wall, and gently cut the membrane which holds the soft brown organs to the wall. They will then fall down and lie in the arm. Serve each ray in the same way. Then carefully cut away the aboral wall of the central disk. Figure 44 (text) shows a starfish treated in this manner. Note that there are two branches of the soft brown organs in each arm. These organs are the *pyloric cœca*, or "livers," as they are often called. Note that each pair of branches is connected by a small tube with a large membranous pouch over the mouth. This pouch is the stomach. The stomach is often found protruding from the mouth. Turn to the text and find out how the starfish procures its food. Note the short gullet leading from the mouth to the stomach. There is also a short intestine leading from the stomach to an opening through the aboral wall. To the intestine is attached a small convoluted, branched tube, the *intestinal cœcum*. Trace the intestine to its outlet and find the intestinal cæcum.

Remove the pyloric cæca. Note on the floor of the ray two double rows of white globular sacs. These are the *ampullæ*. They are connected with the tube feet and are filled with a watery fluid which, when the ampullæ are contracted, is forced into the tube feet, thus lengthening and expanding these organs of locomotion. There are two glandular, reproductive organs in each arm. They lie at the very base of the arm where the latter joins the disk. In some specimens, depending upon the maturity of the animal, these organs reach almost to the tip of the ray,

while in younger individuals they are not more than half an inch long.

Make a drawing showing these structures.

The nervous system. — Part the rows of tube feet along the middle of each ray and note a yellowish, white ridge, the *nerve* of the ray. Trace this nerve to the mouth and find the *nerve ring* that surrounds the mouth. Again, trace the nerve of the ray to its outer extremity and find a red spot, the *eye-spot*. The eye-spot is situated at the base of a so-called tentacle which resembles a tube foot, but is smaller and has no sucking disk.

Diagram the nervous system.

The water-vascular system. — If a fresh specimen can be obtained, cut off the tip of a ray. Note the small tube that runs along the floor of the ray. With a fine pointed syringe, inject some carmine into this tube. The vessels connected with it can then be easily traced. Many of them can be made out with an alcoholic specimen not injected. Note that just inside the mouth, around the gullet, is a five-sided canal, the *ring canal*. A hard tube runs from this to the madreporic plate, called the *stone canal*, because its walls contain a series of calcareous rings. From the ring canal radiate five canals, one for each arm. These are the *radial canals*. Their cut ends may be seen at the tip of the cut-off rays. The tube feet are connected to the radial canals by short tubes running to the right and left. This whole system of tubes is called the *water-vascular system*. (See text for manner of locomotion by means of this system.)

Make a diagram of the water-vascular system.

C. Topics for Further Study. Compare several starfish, noting the differences in size and shape of the arms and central disk. Compare with the brittle stars and sea

urchins. Note the spines on the body of the sea urchin. Remove the spines and note the globular shell. Note the five areas of the sea-urchin's shell.

To what branch does the starfish belong? What other animals belong to this branch? What is characteristic of the skin of the starfish? What kind of symmetry has its body? All the members of this branch possess the same body symmetry. Compare with the symmetry of the body of the locust. Note that the starfish has a set of tubes for the circulation of water. What is the nature of the organs of locomotion? Most of the other members of this branch possess the same kind of organs. Make a summary of the digestive organs of this echinoderm.

X. — The Earthworm

Materials. — Living and preserved earthworms, piece of glass, tooth picks, dissecting instruments, wax-lined dissecting pan, pins, magnifier.

Directions. — (Earthworms may be obtained after a warm rain in spring by simply picking them from the ground. Failing in this, they may be procured by digging in the soil. They will be found more abundant in rich soils. Large specimens for dissection may be had of dealers in such supplies.)

A. Study of a Living Earthworm. Place a live worm on a rough surface, for instance, the top of a table or sheet of paper. Watch its movements. Does it move with the same end always foremost? Can it move backward? Does it hold the same side of the body uppermost? Turn it over and note the results. Note the lengthening and shortening of the body when it moves. Has the earthworm any visible locomotor appendages?

Draw one backward across the hand. What is the sensation? What is this due to? How many rows of the bristles are there? (Use the magnifier to determine this.)

Place the worm on a piece of glass. Can it progress? Why this difference in the progression of the earthworm on a smooth and on a rough surface? What are the bristles, or *setæ*, for? Determine which way the setæ point.

Determine the sensitiveness of different parts of the body by touching it in different places with the tooth pick.

Note the blood tube along the middle of the back just under the thin, transparent skin. Can pulsations in this tube be seen? If so, they would indicate a circulation of the blood. Determine, if possible, which way the blood is flowing in this tube.

B. EXTERNAL FEATURES. Note the long, tapering, cylindrical body. Is it one unbroken cylinder like a pencil? The rings are called *segments*. How many segments are there in the body? The end of the body that was usually carried foremost while the worm was moving is the *anterior end,* and the opposite end is the *posterior end.* The side of the body held uppermost away from the ground is the *dorsal side,* and the opposite side is the *ventral side.* Is there any difference between the dorsal and ventral sides in color and shape? If a cross section of the body were made, would it be a perfect circle? Which side would be flat and which would be round?

Note that if the worm were cut in half lengthwise the right half would be similar to the left half. This two-sided likeness is known as *bilateral symmetry*, and the earthworm is a *bilaterally symmetrical* animal.

Note the thickened, or swollen ring, the *clitellum,* near the anterior end. Does it embrace more than one segment?

Find the mouth at the anterior end of the body. Note that it is overhung by a projection, the lip, or *prostomium.*

Find the anal aperture, or vent, at the posterior end of the body.

Make a drawing of the body from a dorsal view.

C. INTERNAL FEATURES. With sharp scissors, make a shallow incision through the skin, along the median line of the back, the whole length of the body, being very careful not to injure any of the organs beneath. Draw the edges of the cut skin apart and pin down with ribbon pins, beneath water in the dissecting pan.

Note the delicate partitions, or *septa,* across the body cavity, dividing it into chambers corresponding to the ring-like divisions of the walls. Note the alimentary canal extending as a straight tube the whole length of the body. It consists of a pharynx, gullet, crop in segments 15 and 16, and a gizzard in segments 17 to 19. The remaining part is the intestine.

Note three pairs of large white bodies surrounding the gullet. These are the *seminal vesicles.* Posterior to these are two smaller sacs, the *seminal receptacles.*

Note the large blood vessel on the dorsal side of the alimentary canal. In segments 7 to 11 will be seen several branches from this blood vessel going around the alimentary canal and meeting a ventral blood vessel below.

Make a drawing showing these organs.

Cut the alimentary canal in two at the pharynx and remove the posterior portion. Note the ventral blood vessel beneath. Beneath this note the large white double cord running the whole length of the body. This is the nerve cord. Note in each segment a white knot, or swelling, a *double ganglion.* Trace the nerve cord forward and

cross section of the body showing the organs. Summarize the processes of digestion, circulation, excretion, and respiration as carried on in the earthworm.

XI. — The River Mussel

Materials. — Living mussels, carmine or India ink, dissecting instruments, dissecting pan, magnifier, hydrochloric acid, balances, bristles.

Directions. — (The following outline applies especially to the river mussel (Unio) that is common in the ponds and streams of the United States. The marine clams (Venus and Mya) will serve quite as well. These may be obtained of dealers in zoölogical specimens. The river mussel may be carried home in water, and kept in an aquarium containing several inches of sand in the bottom.)

A. Study of a Living Mussel. Carefully watch a living specimen in the aquarium. In what position is the shell held when the animal is moving? Is the movement slow or rapid? Does the mussel leave a track, or furrow, in the mud? Is the shell open or closed when the mussel is moving? Note a white fleshy projection between the anterior edges of the shell. This is the *foot*. Note that the mussel moves in one direction with the anterior end foremost. Is the broad or sharp edge of the shell held uppermost? From the posterior edges of the shell may be seen projecting two rounded, fringed openings, the *siphons*. By placing some carmine or India ink in the water near them, the direction of the currents of water may be determined. Through which siphon does the water enter? Through which does it emerge? In moving, the valves are held partly open and the edge of the delicate mantle may be seen all around the edges of the shell.

B. External Features of the Shell. Of how many pieces is the shell composed? Are they of the same shape and size? These pieces are called the *valves*. Note that they are joined or hinged together along the broad edges. These edges are held uppermost by a living mussel when it is moving, and this side of the shell is therefore known as the *dorsal margin*. The thin edge of the shell is called the *ventral side* or *margin*. Note the concentric lines running parallel with the ventral edges of the shell. These are the *lines of growth*. They all begin and end around a raised point near the anterior end of each valve. This point is called the *umbo*, or *beak*.

Knowing the dorsal side of the shell and its anterior end determine which is the right valve and which the left.

Draw a side view of the left valve showing all the foregoing points possible.

C. The Mussel in the Shell.

(For dissection, the valves must be opened. To do this, place the animal in warm water, about as hot as the hand can bear. The valves will gape, and a block may be slipped between them to hold them open.)

Note the mantle lining the inside of the valves. With the handle of a scalpel, separate the edge of the mantle from the upper valve. Observe that it is loose to a line some little distance from the edge of the valve. Beyond this line the mantle is grown tight to the valve. This line is known as the *pallial line*. With the scalpel, carefully tear the mantle loose from the valve that is uppermost, and then cut away the strong muscles that hold the valves together. Note that the valves spring apart as this is done. Find the strong *ligament*, near the umbo, that acts as a hinge. Note the hinge teeth on the dorsal edges of

the valves. Observe how closely they fit together. Remove the uppermost valve.

(Further dissection is best done under water. The water will cause the different parts to float separate from each other so that they may be easily distinguished.)

Note that the mantle lines the inside of both valves and completely surrounds the body. Observe the two siphons at the posterior end of the shell. Note that they are formed by the mantle. The lower one is the *inhalent* and the upper one the *exhalent siphon.* Note at each end of the shell a very large thick muscle that was cut by the scalpel. The muscle at the posterior end is the *posterior adductor muscle.* The one at the anterior end is the *anterior adductor muscle.* They hold the valves tightly shut. Observe beside each one smaller oblique muscles, the *anterior* and *posterior retractor muscles,* respectively.

Turn back the half of the mantle torn from the valve. The space inclosed by the two lobes of the mantle is called the *mantle cavity.* In this mantle cavity, as the lobe is turned back, note the two pairs of thin, ribbed *gills,* a pair on each side of the body. Note the soft white *abdomen* between them. The water, laden with food, is taken through the inhalent siphon into the mantle cavity. The food is passed into the mouth, but the water passes through the gills, aërating the blood, and finally goes out through the exhalent siphon.

Loosen the mantle and body on the dorsal side very carefully and pull them a little from the remaining valve. This will bring the dorsal side of the body into view. On the middle line of the dorsal side cut carefully through the mantle and the other delicate tissue until a cavity is laid

open. This is the *pericardial cavity.* Within it, is a dark tube, the intestine, which runs straight through the cavity. The *ventricle* of the heart surrounds the intestine about midway of its length. The *auricles, right* and *left,* are attached to the right and left sides of the ventricle, respectively. The blood is brought to the auricles from the gills by the two *branchial veins,* one to each auricle. It is then emptied by the auricles into the ventricle. From here it is forced through the *anterior* and *posterior aortas* to the different parts of the body.

On either side of the front part of the abdomen are two soft, triangular flaps, the *labial palpi.* Between these and directly in front is the *mouth.* It leads by a short *gullet* to the *stomach,* which is surrounded by a dark mass, the *liver.* The liver is plainly discernible. The intestine may be traced from the stomach by using a bristle. It makes several turns before it runs through the pericardial cavity. Remove the heart and note beneath it the *kidneys,* or *renal* organs.

Beneath the posterior adductor muscle is a pair of yellowish *white ganglia.* These are the *visceral ganglia.* They give off several nerves that run to the mantle and gills. Two nerves also run from the visceral ganglia to join a pair of *ganglia* near the mouth. From the latter, a pair of nerves run to the *pedal ganglia,* which lie deeply imbedded where the foot and the abdomen meet.

Make a drawing showing as many of these points as possible.

D. INTERNAL FEATURES OF THE SHELL. Remove the body of the mussel from the shell.

Note the color of the shell lining and its smooth, pearly finish.

find where it divides near the anterior end. One branch goes up one side of the gullet and the other up the opposite side, after which they meet on top of the alimentary canal to form the brain.

In most of the segments will be seen a small, much convoluted tube, the *nephridium*. The nephridia are the organs of secretion. Each one opens outward on the ventral side of the body through a pore. They carry off the waste products of the body.

The earthworm is hermaphroditic and has both the male and female reproductive organs. Beneath the seminal vesicles already noted will be found the *testes*. These open outward through a pair of ducts that extend backward to the fifteenth segment.

The *ovaries* may be found, with difficulty, in segment 18. They are a pair of small white bodies. The *ova* pass from the ovaries into funnel-shaped oviducts that open on the ventral side of the body through segment 14.

Make a drawing showing these points.

D. Field Study of the Earthworm. Study the earthworm in the field. When is it found on top of the ground, during the night or day, when the air is dry or moist? What is the shape of its burrow? How deep is the burrow? What is often found piled around the mouth of the burrow? These are pellets of earth and refuse food that have passed through the alimentary canal and are termed *castings*. Note the ease and quickness with which an earthworm can retreat into its burrow. Note how difficult it is to pull one out of its burrow. Why is this?

E. Topics for Further Study. Write out the chief characteristics of the earthworm, remembering the division of the body into definite segments. Make a diagrammatic

XII. — The Squid

Materials. — Specimens of squid.

Directions. — (The squid is a marine mollusk. It is common along the shores of the United States, and may be obtained from any of the dealers in zoölogical supplies. A half dozen or so should be in the collection for comparison with the clam and other mollusks.)

Note the long, cylindrical body, with a distinct head. Does it possess a shell like the clam or oyster? Imbedded in the thick mantle straight down the back is a rudimentary shell known as the *pen*. Did the clam possess a distinct head? Note on the head of the squid the long arms, or tentacles. How many pairs are there? Note that one pair is longer than the other pairs. Note the sucker disks on the inside of the short arms. Note that the long arms do not bear the suckers the whole length, but only on an expanded portion near the end. How many rows of the cuplike suckers on this expanded portion? Are they all of the same size? Note in the middle of the cluster of arms, at their bases, the mouth. Note the black, horny beak, something like the beak of a parrot.

How many eyes has the squid? Where are they? Did the clam have eyes? At the posterior part of the body, note the triangular flaps of skin. These are the so-called fins. They are used to guide the animal in swimming.

Make a drawing of the dorsal side of the animal.

Beneath the skin of the body are numerous pigment cells. They appear like freckles all over the dorsal side and are usually purplish in color. These cells can be expanded until they touch one another or suddenly contracted

until each one stands by itself as a minute dot. At every successive contraction and expansion of the pigment cells, in a living specimen, blushes of different hues may be observed passing over the body.

Note that the head seems to sit down in a collar of thick skin, or flesh. This is the anterior end of the thick, fleshy mantle that covers all of the body except the head. Is the head grown to the mantle? How does the mantle compare with the mantle of the clam? Beneath the head, note the siphon. Under ordinary conditions, the water, for respiratory purposes, passes in and out through the aperture between the mantle and the neck. But when the animal desires to swim the mantle contracts and closes up the opening about the neck, and the water is forced out through the siphon.

Make a written comparison of the clam and squid.

XIII. — The Habits and Life History of a Pond Snail

Materials. — Specimens of Physa (alive).

Directions. — (The two common pond snails, Limnea and Physa, are abundant in many ponds. They may be dipped up and kept in jars of water almost any length of time, if some pond scum and lettuce leaves are added for them to eat. The following outline applies especially to the smaller one, Physa.)

A. Study of a Living Snail. Note the color of the shell. What is its shape? Is it a flat or an ascending spiral? Does it coil to the right or left? Note that it consists of one piece or valve. Compare it with the clam. Watch some of the individuals climb up the sides of the jar. They progress swiftly, with a smooth, gliding move-

ment. Some will be seen swimming along the surface of the water. In what position are they? Note the movements of swimming. Note that the portion of the body outside of the shell is triangular in shape. The greater part of this is the foot. Note in a swimming specimen the mouth, which is a small aperture that opens and shuts rythmically. It is on the under side of the head. Note that the triangular foot ends squarely just behind the head. Watch one come to the top and turn on its back. As it does so, note the round opening just inside of the shell. This is the respiratory opening and it leads to the lung. The snails come to the surface at intervals to take in air through this opening. Touch an individual with a pencil. Does it drop to the bottom? As it does so what does it give off? The lung is used as a hydrostatic apparatus as well as for breathing. When the snail wishes to descend for safety, it gives out from the lung one or more bubbles of air; this causes the body to become heavier.

Make a drawing of the snail, as it is swimming on the surface of the water, to show its foot and head with the mouth.

How many tentacles has this snail? Where are the eyes? How many are there?

Make a drawing of the shell from above.

B. LIFE HISTORY OF THE SNAIL. If these snails were brought into the house in February or March, the eggs may soon be found on the sides of the jar, or on leaves, sticks, etc. They will appear as transparent, gelatinous masses, about the shape and size of half of a pea or bean. Note the number of eggs in each mass. Mount a few of them on a slide, and examine with a $\frac{1}{8}$ objective. What is the shape of a single egg? Note the transparent capsule, like a shell, about each one. If they are nearly

fresh eggs the embryo may be seen, occupying only a very small portion of the egg. As they grow older the embryo enlarges, the shell begins to form, and the young snail keeps constantly turning round and round in the egg. At this stage, note the two dark spots — the eyes — on the head.

Make a drawing showing a young egg with its nearly spherical embryo, and then an older stage, with the more advanced embryo.

If possible, keep the eggs until the young snails come out. Note the time it took the eggs to hatch.

These snails have the power of spinning a thread, which they may use to ascend or descend in the water.

Limnæa lays its eggs later in the season in much the same situations. Limnæa should be fed daily on cabbage or lettuce leaves. On these leaves, areas that have been scraped by the lingual ribbon of the snail may be seen.

XIV. — The Crayfish

Materials. — Specimens of crayfish (alive and preserved in formalin), dissecting instruments, dissecting pan.

Directions. — (The crayfish is common everywhere in brooks, ponds, and pools. In many localities, especially in the southern states, some species dig holes in the ground and build clay chimneys about the mouths of the tubes. Crayfish may be caught by hook and line or scooped up with a net.)

A. Study of a Living Crayfish. It will be of great interest to observe them in their natural homes. Note the manner of movement in the water. In how deep water do they live? In what character of soil do those live that build chimneys? How deep are the holes? Determine, if possible, what is at the bottoms of the holes. Do the cray-

fish ever come out of their burrows? Is the inside of the burrow smooth or rough? How high is the chimney and how is it constructed? Does this crayfish ever do any harm? On what does it live?

Catch a live specimen and put it in an aquarium. Note its manner of movement. How many legs does it use in locomotion? Poke a stick or straw at its head. Which way and how does it move? How is the abdomen held? Note the eyes of the animal. Note its feeding habits. What does it eat? How does it catch its prey?

B. External Features. Note that the body of the crayfish is divided into two principal regions. The anterior region consists of the head and thorax joined together and appears as one piece. This is called the *cephalothorax.* The posterior division is the *abdomen.* Note that the abdomen is plainly segmented. Does this aid in the movements of the animal? Note that the whole body is encased in a hard covering, or crust. This crust is hardened by a deposition of *lime carbonate.* As the crayfish grows, this crust, or hardened skin, is shed from time to time.

Make a drawing of the crayfish from above.

Note that the cephalothorax, when viewed from above, shows no signs of being segmented. Look on the ventral surface, however, and the division into segments may be seen. Note that the top of the cephalothorax is covered with a single large piece called the *carapace.* The division between the head and thorax is marked by a shallow groove that runs transversely across the carapace, and then continues forward in an oblique direction on each side. Note that the carapace in front extends forward between the eyes, forming a concave pointed beak. This is known as the *rostrum.*

Note the number of segments in the abdomen. How many appendages does the fourth segment, for instance, bear? What is the general shape of this segment, and on what part of it are the appendages borne? The convex piece on the dorsal side is called the *tergum*. The piece on each side that slopes like the side of a roof is called the *pleurum*. The transverse piece on the ventral side between the two appendages is called the *sternum*. How are the segments of the abdomen connected with each other? Why?

The appendages of the crayfish. — Now look at the end of the abdomen and note that it ends in five flaplike bodies, each fringed around the end. The broad middle flap is the last segment of the abdomen, and is known as the *telson*. The two flaps on each side of the telson are the greatly modified appendages of the next abdominal segment anterior to the telson. These flaps are in pairs, and, together with the telson, form the *tail fin* of the crayfish.

The crayfish has nineteen pairs of appendages. Note that the last segment, the telson, bears no appendages. The next segment, the sixth, bears the two pairs of fringed flaps that have already been spoken of as forming a part of the tail fin. The next five abdominal segments bear each, one pair of appendages, which are called the *swimmerets*. These appendages are all alike except those on the first and second segments, which are reduced and smaller, or perhaps lacking entirely in the female.

Note that each appendage consists of a short, twice-segmented stalk, bearing two narrow, flat, fringed filaments, like a two-tined fork.

The next five pairs of appendages are the legs attached to the thorax. Note that the fourth and fifth pairs end

with one short claw, while the other three pairs end in double claws, which are very large on the first pair. How many segments in each leg?

After having examined the appendages as directed, begin at the most posterior one, and remove those of the abdomen from the right side, being careful to keep them in their proper order. When the legs are reached, before removing them, expose the gills. To do this begin at the posterior end of the carapace, and cut through it with a pair of scissors, along the middle, until the line separating the head and thorax is reached. Then follow this line to its anterior end. Break off the piece of the carapace so cut, and the gills will be exposed. Note their feathery appearance. Note that they lie in a chamber completely hidden from above by the carapace. Do they fill this chamber? Where does the water get into the chamber? Note that the gills are arranged in layers, or series. One layer, or series, is attached to the bases of the legs while the other series is attached to a thin, transparent membrane. Now remove each leg with its gill and lay them in order after the other detached appendages. The thorax has three more pairs of appendages immediately in front of the large pair of legs. These three pairs entirely cover the mouth. Push them to one side and note the mouth hidden by them. These appendages are called the foot-jaws, or *maxillipeds*. They are used to aid in grinding the food.

Remove the posterior maxilliped. Note that it, like a swimmeret, has a twice segmented stalk with two branches, but, unlike the swimmeret, it bears a gill. Remove the next maxilliped. Has it all of the parts of the first one? What is the difference in the size of the two detached maxil-

lipeds? Remove the next, or first, maxilliped. Has it a gill? How does it compare in size with the other two? This completes the appendages of the thorax, for the remaining ones belong to the head.

The next two pairs of appendages are thin and delicate, and one must hunt for them carefully. They correspond to the lower jaws of the locust, and are given the same name, *maxillæ*. After they have been located and separated from each other (they lie directly in front of the first pair of maxillipeds), note a sort of curved, spoon-shaped plate on the second maxilla. It moves back and forth in the anterior opening of the gill chamber, and scoops the water out of the chambers, as it were, thus giving opportunity for fresh water to enter from behind. The next pair of appendages is the *mandibles*. Each is hard, with toothed edges, and each has attached to its anterior edge a short, curved appendage, known as the *palpus*. These should be compared with the mandibles of a locust.

Now note the next pair of appendages, the two long *antennæ*. Above each antenna, but beneath the eye, is a flat, bladelike branch of the antenna. It probably protects the eye. Note that the eyes are stalked. Pull out the eye and note the length of the stalk. The stalk can turn the eye so that it can look in any direction.

Lastly note the pair of small, branched antennæ known as the *antennules*.

Make a drawing of all the appendages of the right side after having placed them in order.

Note the great similarity in structure of these organs notwithstanding their diversity of function.

C. Topics for Further Study. To what branch does the crayfish belong? What other animals belong to

this same branch? To what class does it belong? Name the other animals belonging to the same class. Compare the crayfish with a lobster.

Sum up the chief characteristics of the crayfish. Fix firmly in mind its position in the animal kingdom. Give a summary of its habits, food, habitats, and economic importance. Write out a comparison between it and the locust.

XV. — Other Crustaceans

Materials. — Specimens of cyclops, cypris, daphnia, crabs (Rock and Hermit); watch glass.

Directions. — (Cyclops, cypris, and daphnia are small crustaceans that live in fresh-water ponds. They may be obtained in abundance in jars of pond water containing Algæ that have been brought into the laboratory. Though small, they are visible to the unaided eye.)

A. Cyclops. Take some of these out in a watch crystal, and observe, carefully, their movements. Is the progression a smooth, gradual one or a jerky one? Their mode of motion has given them the name of "water fleas."

Note the shape of the body, large at the anterior end and tapering to the posterior end, convex above and flat below.

Note the one dark eye at the anterior end of the body on the dorsal side. Note the two long appendages at the anterior end of the body, called the *antennules*. There is also a pair of short *antennæ* that are often hidden beneath the head. Observe that there are five pairs of appendages on the ventral side of the body. The body is segmented, but note the large piece covering the anterior end of the body. This is the *carapace*. The tip of the abdomen ends

in forked stylets. Attached to each side of the first abdominal segment of the females will often be found a sack of eggs.

Make a drawing showing all these points.

B. Cypris. It is usually found with cyclops but differs from most crustaceans in having a bivalved shell. It is often mistaken for a mollusk. The shell is really composed of the carapace, which is divided into two parts. The halves are hinged along the dorsal edge like the valves of a clam. Within the shell are seven distinct pairs of appendages which betray the family connections of this little animal.

C. Daphnia. Sometimes the aquarium is alive with these grotesque, hump-backed crustaceans that travel with a jerky motion like cyclops. The whole body is covered with the carapace. The head is drawn down, and the back is humped up like a stooping, round-shouldered man. The antennæ are long and are thrown out in front. Note the five pairs of leaflike swimming feet.

D. Crabs. If possible, get a rock crab for the collection. Compare it with the crayfish. Note the greatly broadened carapace. Note the abdomen, which is curled beneath the cephalothorax and is permanently carried there. Compare the antennæ and the antennules with those of the lobster.

Hermit Crab. If one of these is in the collection, note the soft abdomen. Why does this crab need a shell, and the rock crab not?

XVI. — The Locust, or Grasshopper

Materials. — Specimens of locusts alive and preserved, glass slides, cover glasses, compound microscope, glass bell jar, dissecting pan, pins, dissecting instruments.

Directions. — (For the field work, the Carolina locust will serve as well, if not better, than any other species; but wherever the American locust is available it will be found better for dissection because it is much larger. The Carolina locust has dark hind wings with yellow borders, is found along the roadsides, and is dusty-gray in color. The American locust is considerably larger and has nearly transparent hind wings.

An abundant supply of specimens may be caught with a net and preserved in eighty-five per cent alcohol, but fresh specimens are more desirable for dissection. Care should be exercised to get both males and females for comparison and the nymphs in all stages of development. The nymphs may be recognized from their lack of fully developed wings.)

A. Field Study of the Locust. Study the Carolina locust in the field. . Where are they found? Watch and describe their habits of flight. How far do they usually fly? Do they make any noise during flight? Are they easily seen after they alight? Why is this? What color are they? What kind of places do they usually choose to alight upon? Have they any method of locomotion other than that of flight? When are they most active? Determine by observing them on warm and cool days and on frosty mornings and at noontide. What effect then has temperature upon their activities? Have they any enemies? How are they protected from their enemies?

B. Study of a Living Locust. Place the locust under a large glass jar and note its manner of walking. Note the positions of the legs in the succeeding phases of walking. How many legs has the locust? Note their variation in size. Allow one to go free, and note what legs are used in leaping. How far can it jump?

Note the respiratory movements of the abdomen. Count the number per minute. Does it vary in different indi-

viduals or under excitement? Withhold food for half a day from a specimen and then offer it fresh clover or lettuce leaves and note its manner of eating.

C. External Features. Note that the body is composed of three great divisions: head, thorax, and abdomen. Is the abdomen similar in any way to the body of an earthworm? Examine the thorax and note that, like the abdomen, it is divided into segments, but that the division lines are not so plain as on the abdomen. The head is apparently not segmented. Actually it is composed of several segments so closely grown together that it is impossible to distinguish them.

The head end of the body is known as the *anterior* end, while the opposite end is called the *posterior* end. When the animal is in its normal position for locomotion on the ground, the side of the body next to the ground is known as the *ventral* side, while the opposite side, or back, is called the *dorsal* side.

Note that the right and left sides of the body of the locust are alike. That is, this animal is *bilaterally symmetrical.* This form of structure is characteristic of those animals that move swiftly.

Head. — Note the two large compound eyes. Tear off a piece of the eye and mount on a slide in water beneath a cover glass. Examine with the low-power objective. How does it appear?

Make a drawing of twelve of the hexagonal divisions. Each one of these divisions corresponds to a simple eye, and all of them taken together constitute a compound eye.

Note the round simple eye, or *ocellus,* in a groove in the middle of the forehead. Note a simple eye at the upper, inside corner of each compound eye.

Note two long slender appendages on the head. Are they segmented? These are the *antennæ*, or feelers. Pull one off close to the head, mount it under the microscope, and count the segments.

Make a drawing of one.

Note the broad, notched flap at the lower end of the face. Lift it up and detach. This is the upper lip, or *labrum*.

Make a drawing of it.

Just beneath this, note two hard black bodies. These are the *mandibles*. Detach them both. Note the tooth-like projections on the inside edges.

Make a drawing of both.

Beneath the mandibles, note two *maxillæ*. Each one consists of several pieces. Each also bears a slender, segmented appendage called a *palpus*. The two palpi are known as the *maxillary palpi*.

Make a drawing of each.

Lastly, note the under lip, or *labium*. It bears two slender, segmented appendages, the *palpi*, similar to those of the maxillæ. Do they have the same number of segments? They are called the *labial palpi*.

Make a drawing of the labium, with its palpi.

Thorax. — Note that this part of the body is composed of three divisions, or segments. They may be easily seen on the under side, because each one bears a pair of legs. The segment next to the head is called the *prothorax*. The next is called the *mesothorax*, and the last, the *metathorax*. The mesothorax and metathorax each bear a pair of wings.

How many wings are there? Where are the hind wings carried? Are they expanded or folded? Detach all wings. What is the relative size of the two pairs? How do the hind wings differ from the front ones?

Make a drawing of a front wing and a hind wing.

Detach a front leg. Note that it is composed of segments of unequal length. The first one is called the *coxa*. It is short and globular. The second segment is the *trochanter*, the third *femur*, fourth *tibia*, and the remaining ones are called the *tarsal* segments. The last tarsal segment bears a pair of claws.

Make a drawing of a leg.

Abdomen. — Note that between the segments is soft, flexible skin, which furnishes freedom for movement. Note that the skin of the segments is hard and smooth. This is due to a hard horny substance called *chitin* that is deposited in the skin. On each side of the first segment is an oval transparent membrane that constitutes the ear of the insect.

On each side of each segment, near the front margin, will be seen a small aperture. These are the openings, termed *spiracles*, through which the insect takes in air.

The last segments bear in the female two pairs of strong curved organs. These compose the *ovipositor*. They are used to make holes in the ground in which to lay the eggs. The end of the abdomen of the male is blunt and rounded, and bears three inconspicuous appendages.

D. INTERNAL FEATURES. With head directed from you, pin a freshly killed female locust on its ventral surface in a dissecting pan, by spreading the wings and pinning them securely to the wax or cork. Run a pin through the posterior end of the abdomen into the cork. With a pair of scissors cut carefully, from the ovipositor to the head, just through the skin, on the dorsal side, a little to the left of a median line. With a forceps lift away the skin on the right of the slit and note the delicate, whitish blood vessel, the *heart*. Where does the heart lie? How long is it?

Does it extend outside of the abdomen? It will take careful dissection to find the heart and not injure it. Often it may be seen best by dissecting the abdomen from the ventral side. Now cut along the right of the median line, parallel with the first slit, and lift away the skin from the roof of the abdomen.

Note the white, silvery air tubes (*tracheæ*) (page 161 of the text) ramifying throughout the body. Note the large longitudinal tracheæ running along the sides of the abdomen. How are these connected with the spiracles?

Make a diagram of the tracheal system showing the connection with the spiracles.

Mount some of the tracheæ under a microscope and note their appearance. A spiral elastic fiber is coiled inside the wall of each tube to hold it open.

Make a drawing of a piece of a trachea.

There are usually two masses of yellowish, cylindrical eggs in the abdomen of the female. The eggs are piled in tiers on the sides and top of the alimentary canal. Note a white tube, the *oviduct*, running posteriorly from each egg mass to the ventral side of the abdomen. Here the two oviducts unite and form a tube, the *vagina*, which opens to the outside between the ovipositors.

Remove the egg masses and note the long, straight alimentary canal, running from the head to the posterior end of the body. Begin at the mouth and trace it, noting the following parts: —

The *esophagus*, or *gullet*, which runs from the mouth upward through the head and then posteriorly into the thorax.

In the thorax the esophagus enlarges into a large food reservoir, the *crop*, in which the food is held for a time

and ground up, as it were, into fine bits. Note the delicate, white *salivary glands*, one on each side of the crop. They connect with the mouth by means of two *salivary ducts*.

Succeeding the crop, but not distinctly separated from it, is the *proventriculus*, or *gizzard*. Like that of a chicken, the locust's gizzard has thick, muscular walls for comminuting the food. At the posterior end of the gizzard there is a circle of rather large, conspicuous appendages, the *gastric cœca*. Note their shape, number, and manner of attachment to the alimentary canal. Their function is to secrete a digestive fluid.

Succeeding the gizzard is the stomach, or *ventriculus*. It is not sharply differentiated from the other parts of the alimentary canal adjacent to it. Several long slender tubules arise from the posterior end of the stomach and float free in the body cavity. These are the *Malpighian vessels* (page 163 of the text). They take up impurities from the blood and carry them off through the intestine. Their action is urinary, similar to the kidneys of the higher animals.

The remainder of the alimentary canal is the intestine.

Make a drawing of the alimentary canal showing all the parts spoken of above.

Trace the course of the food from the time it enters the mouth, and show how it is acted on in the different organs of the digestive system. After the food leaves the stomach its nutritive portion is absorbed directly through the walls of the intestine by the blood, which carries it to all parts of the body.

Remove the alimentary canal.

Note a double, white cord running along the floor of the body cavity. Note that these two threads are connected

in many of the segments by a double knot, or *ganglia.* Note the smaller nerves that are given off from each pair of ganglia. Trace the double cord to the head. Note that the cords separate, one cord passing up the right side of the esophagus and one up the left side. Note also that the cords join again on top of the esophagus and that each one is enlarged at the end to form a large double ganglion, the *brain.*

Make a diagram of the nervous system.

E. Topics for Further Study. Make a summary of the points to be drawn from this exercise; namely, the habits, habitats, food, and movements of the locust, the divisions of the body, number and kinds of eyes, number of legs, antennæ and wings, the breathing organs, digestive organs, circulatory organs, and organs of excretion. Fix in the mind the position of this insect in the animal kingdom. To what branch, class, order, family, genus, and species does it belong? Compare it with other members of the Arthropoda; namely, spiders, lobsters, centipeds, and insects. Make a summary of its leading characteristics.

XVII. — The Cabbage Butterfly

Materials. — Specimens of cabbage butterfly, camel's hair brush, alcohol, glass slides, cover glasses, compound microscope, hydrochloric acid, hypochlorite of sodium, carbolic acid crystals, oil of turpentine, Canada balsam.

Directions. — (The large milkweed butterfly, or the white cabbage butterfly will answer for this exercise. The milkweed butterfly is also known as the Monarch, and is figured in the text.)

A. External Features. Observe the divisions of the body. Do they correspond to those of the locust? What

is found all over the body? Were the same structures found on the body of the locust?

Note the two large compound eyes. With a camel's hair brush, carefully remove the scales from the head. Are there any simple eyes? There is no movable flaplike labrum as in the locust. The labrum is small, narrow, and runs transversely across the head. It bears at each end a tuft of fine hairs. Note that there are no mandibles. Note that there is a long proboscis coiled up beneath the "chin." This is made up of the two *maxillæ*, grooved on the inner sides and joined together to form a tube. If the specimen is fresh, the tube may be uncoiled. If it is dry or has been in alcohol, soak the head in warm water until it is soft. The under lip, or labium, is also immovable and forms the under side of the head. Note the two hairy projections pointing upward in front of the head. These come from the labium and are the *labial palpi*. Compare the antennæ with those of the locust. Are they segmented? What is the shape of the antennæ at the ends? This shape is characteristic of the butterflies.

Make a drawing of a side view of the head showing as many of the above points as possible.

How many wings has the butterfly? How do they differ from those of the locust? Are they folded at any time? How are they held when the insect is at rest? To determine this, living specimens must be observed in the field. Brush off some of the scales and mount them in alcohol. Examine with the low-power objective and note the shape. Note that the scales differ considerably in size and shape. All gradations may be found from hairs to flat scales. In fact, the scales are modified hairs. Note the longitudinal ridges, or *striæ*. Note the small pro-

jection, or handle, by which the scales are attached to the wing membrane. Examine the wing where the scales were removed, and note the manner in which the scales were laid on the wing. With a brush, carefully remove all the scales from the wing, both above and below. Better still, dip the wings in alcohol, then immerse them for a minute in dilute hydrochloric acid (one part acid to nine parts water), and then place them in Labaraque solution (hypochlorite of sodium), until clear and transparent. Finally place them in alcohol again until they rise and float. Then mount them in alcohol for immediate study.

(If it is desired to make a permanent mount one should proceed as follows: Transfer the wing from the alcohol to a clearing mixture (two parts by weight of carbolic acid crystals and three parts of rectified oil of turpentine) and allow it to remain there ten minutes. Finally transfer it, together with some of the clearing mixture, to a glass slip, put some Canada balsam on top, and cover with a cover glass.)

Note that the wing is transparent. Observe the veins running lengthwise of the wing. Note the few cross veins.

Make a drawing of the right front and hind wings showing all the veins in each.

How many legs has the butterfly? Note that each one is divided into segments. Make out each segment, coxa, trochanter, femur, tibia, and tarsi.

Make a drawing of the leg.

Observe the difference in shape of the thorax from that of the locust.

Make a drawing of a side view of the abdomen.

B. THE LIFE HISTORY OF THE CABBAGE BUTTERFLY. The life history may be followed on cabbage plants in the

field or plants may be grown in the house for the caterpillars to eat.

The eggs are laid throughout the summer on the leaves of cabbage. Obtain some, if possible, and see how long it takes for them to hatch. The eggs are nearly white, conical, and ribbed. They are large enough to be easily seen with the unaided eye and are usually to be found in abundance. If the eggs cannot be obtained, the pale green caterpillars may be found eating the leaves and can be easily fed indoors. They will grow rapidly. Observe the number of times they molt. In two or three weeks each one will change to a pupa. The pupa is known as a *chrysalis*. What color is it? Where is it placed and in what position? How is it attached to the leaf? Watch the chrysalis and see how long before the adult appears. How does the adult get out of the chrysalis?

Watch all these stages and make notes on all the changes and the time occupied in each stage.

From this study of the life history of the cabbage butterfly, it is evident that it passes through remarkable and distinct changes from the egg to the adult. In fact, there are four distinct stages in the life history of this butterfly; namely, the egg, larva, pupa, and adult. An insect that passes through such a series of distinct changes is said to have a *complete metamorphosis*.

C. Topics for Further Study. Give a summary of the life history of the butterfly. Give the characteristics of its wings. Compare its mouth parts with those of the locust. Make a diagrammatic drawing of its body to show the three regions. Find out to what order it belongs. Make a list of other insects belonging to the same order. What is characteristic of all these insects?

XVIII. — The Mouth Parts and Life History of the Squash Bug and the Harlequin Cabbage Bug

Materials. — Squash bugs and harlequin cabbage bugs, magnifier, potassium hydrate, pins.

Directions. — (The squash bug is an ill-smelling, dark-brown insect a little less than $\frac{3}{4}$ of an inch in length. It is common in gardens on squashes, melons, and cucumbers, and the adults may be easily secured during the summer. They should be placed in alcohol or formalin.

In the Southern states the harlequin cabbage bug may be used instead. This bug is known as the "calico back," or "terrapin bug," and is very injurious to cabbages, radishes, and mustard.

Better than either of these, for a study of the mouth parts, is the dog-day harvest fly, or cicada.)

A. External Features. *Head.* — Note the compound eyes. They are not so large as those of the locust or butterfly. Note the simple eyes. How many are there and where are they? Note the antennæ. How many segments in each one? How do they differ from those of the butterfly? Note that the head slopes greatly in front.

Mouth parts. — Note a sharp pointed, immovable, upper lip. At the base of this arises a slender beak that is found pointing backward beneath the thorax between the bases of the legs. Take off the head and mount it on a slender pin, which can then be stuck into a piece of cork to facilitate handling. Examine the beak with the low objective or a hand lens. Is it jointed? How many segments are there? With sharp pointed needles pick the beak apart. Fresh specimens or those preserved in alcohol may be used, but better than either are dried specimens, the heads of which

have been boiled in potassium hydrate (KOH) until they are soft. How many bristles are in the beak? The part of the beak in which they are inclosed is supposed to be the lower lip and labial palpi grown together. These form a sheath to inclose the bristlelike mandibles and maxillæ. Note the groove on top of the lower lip in which the bristles lie.

Make a drawing of the mouth parts.

Recall the structure of the mouth of a grasshopper and the manner in which that insect obtains its food. The squash bug obtains its food by inserting its beak into the tissues of the leaves and sucking up the juices. What can you say in regard to the adaptations of the mouth parts of the grasshopper and of the squash bug to their different functions?

B. Life History of the Squash Bug. The adult insect lives over the winter in crevices or beneath boards or rubbish, and early in the spring lays the eggs in irregular clusters, usually on the under sides of the leaves of squashes, melons, and cucumbers. The eggs are dark yellow-brown, with a glossy surface, and are plainly visible to the unaided eye. Are the clusters of eggs equal in size? How many eggs in one cluster? Are the eggs ever laid singly?

The eggs may be brought into the laboratory and placed on squash plants in breeding cages. It would be more satisfactory, perhaps, to take a breeding cage to the field or garden and place it over a plant and watch the life history of the insect there. It may lend interest to allow the pupils to watch the life history of this insect in their own home gardens. Note the length of time it takes the eggs to hatch. Compare a young nymph with an adult, and note the differ-

ences. Note the number of times that the nymphs molt. Note the process of molting. How long does it take the nymphs to be come adults?

Note that the young squash bugs resemble the adults. What do the adults have that the nymphs lack? From this study of life history, it will be seen that the squash bugs do not pass through any remarkable or distinct changes, for the young resemble the adults. Such insects are said to have an *incomplete metamorphosis*. How does this compare with the butterfly?

The harlequin cabbage bug has an incomplete metamorphosis also.

To what order do these insects belong? Find out what other insects belong to the same order. All of them have an incomplete metamorphosis.

The harlequin cabbage bug lays its barrel-shaped eggs on the leaves of mustard, turnips, cabbage, etc. The life history of this insect may be very easily followed in the garden or in the laboratory. The eggs are conspicuous and easily found.

C. Topics for Further Study. Write out a summary of the life history of the insect studied, giving all the changes. Write a list of the food plants of the insect. Fix firmly in mind the mouth parts and the manner in which these insects obtain their food. Compare with the grasshopper. Bear in mind the kind of metamorphosis possessed by these bugs and the order to which they belong.

XIX. — The Common and Malarial Mosquitoes

Materials. — Eggs and adults of common mosquito (Culex) and malarial mosquito (Anopheles), glass jars, pond scum, watch glasses, magnifiers, glass slides, cover glasses, compound microscope.

Directions. — *A.* Life History of Culex. The common mosquito lays its eggs in summer, in boat-shaped masses, on the surface of the water in rain tubs, ditches, etc. The egg masses are plainly visible to the unaided eye and appear like small patches of soot floating on the water. Find some, take them into the laboratory, and place them on water in some kind of a jar. Note the shape of the egg mass. Which side of the mass is concave and which side is convex? Can the individual eggs be seen with the naked eye? Note that the egg masses appear to be surrounded by a glistening film on the under sides. This is due to a layer of air about them. Push the mass beneath the water. Does it sink? Does it get wet? Break up an egg mass and examine the individual eggs under the microscope. What is the shape of an egg? The wiggler emerges from the larger end of the egg. On which end do the eggs stand when floating in the mass? Why?

Make a drawing of the egg mass and of a single egg.

In a day or two, if the room is warm, the eggs in the jar will have hatched. Note the length of time it took them to hatch after being brought into the house. Take out some of the young larvæ and examine them beneath the microscope. It will be well to put some cotton fibers under the cover glass to entangle the wigglers, in order to keep them in the field of vision. Note the transparent body divided into head, thorax, and abdomen. Note the two dark spots, eyes, on the head. Note the two antennæ with bristles on the ends. Note the bunches of dark hairs on the head near the mouth. Is the thorax any larger than the abdomen? Count the segments in the abdomen. On the caudal end of the abdomen note the long tube.

This is the breathing tube. Note beside it a cylindrical segment (the last) of the abdomen, bearing on its free end some long bristles and four flaps. The flaps function as swimming organs and also, to some extent, as respiratory organs. Note the long bristles along the sides of the thorax and abdomen. Are they branched? Note the tracheæ leading from the breathing tube and running throughout the length of the body to the head. Are there any side and cross branches from the two main tubes?

Make a drawing of the larva showing all these points.

To furnish food for the wiggler put some pond scum into the jar. They ought to grow fast enough in a warm room to become plainly visible at the end of two or three days. Watch them carefully in the water. What position do they occupy? Why? Look at the head and note the movements of the two dark bunches of hair noted above. They create currents of water to bring food to the animal. Do the larvæ remain at the top of the water all the time? How do they get to the bottom? Watch one come to the surface. Is there any difference between its descent and ascent? Is it lighter or heavier than water? How does the thorax compare in size with the abdomen?

Make a drawing of a large wiggler.

Watch the larvæ carefully every day and note any changes that may take place in them. At the end of six to fourteen days dark-colored objects ought to appear in the jars, each with a large anterior end and a slender abdomen. These are the *pupæ* to which the larvæ have transformed. Are the pupæ active? Look closely and note the two tubes on top of the thorax. These are the breathing tubes. Recall the position and number of the breathing tubes of the

larva. Do the pupæ seem to take food? As a matter of fact, they do not. Note the exact time it took a larva to transform to a pupa.

Make a drawing of a pupa.

B. STUDY OF ADULT CULEX. As soon as pupæ are noted, the top of the jar should be covered with mosquito netting to prevent the escape of the adults. Note the time the pupæ exist before transforming to adults. Catch as many adults as possible in cyanide bottles, mount them very carefully on the points of small pins by sticking them into the under side of the thorax. In this way the insects may be handled without fear of ruining them. With the hand lens, note the compound eyes. Note the two antennæ. Examine several specimens and determine whether there is any difference in the antennæ of different individuals. The males have antennæ bearing very many long hairs, while the females have antennæ bearing few short hairs. In addition to the antennæ, the head of the male bears two long, jointed, and hairy appendages termed the palpi. The hairy palpi and antennæ give the head of the male a characteristic appearance, which at once distinguishes this sex from the female. Examine several specimens until there is no difficulty in telling one sex from the other. The male does not bite. Note the single prominent projection from the head of the female. This is the proboscis. Note that there are two very short projections on the head at the base of the proboscis. These are the palpi.

How many wings has an adult mosquito? How does the number compare with that of the butterfly? Note the pair of knobbed threads borne by the metathorax in place of the second pair of wings borne by locusts and butterflies. Mount a wing in water on a slide. Note the longitudinal

veins. Does the wing bear any scales? Where are the scales borne? How does this compare with the wing of a butterfly? With the wing of a locust? Note the shape of the wing.

Make a drawing of a wing showing the veins and scales.

Draw the heads of male and female with appendages.

Note that the body is clothed with scales. Note the long, slim abdomen. How many legs has the mosquito? How do they differ from those of the grasshopper?

C. STUDY OF THE MALARIAL MOSQUITO, ANOPHELES. Malarial mosquitoes usually breed in ditches, in roadside pools of water, or in other clear pools, seldom, if ever, in foul pools. The larvæ of Anopheles lie horizontally just beneath the surface film. They may be collected and the adults reared in the same manner as those of Culex.

Compare the positions, habits, and movements of the larvæ with those of Culex. Note that the head of the Anopheles larva is turned half way round when the larva is feeding. Note how quickly the head is turned to its normal position when the larva stops feeding. Do the larvæ have any markings on the abdomen? How long before they transform to pupæ? How do the pupæ differ from those of Culex? Note the short, wide, respiratory tubes. How long before the pupæ transform to adults?

Compare an adult female with an adult female Culex. Compare the heads of the two females. How many appendages on the head of the Anopheles? How many on the head of Culex that are conspicuous? Compare the positions assumed by the adults of Anopheles and Culex when they alight on the side and top walls of the cages. Make a summary of all the differences between the larvæ, pupæ, and adult females of these two species of mosquitoes.

D. Topics for Further Study. Write out a summary of the life history of a common mosquito. Compare a mosquito with a locust in regard to the divisions of the body, number of legs, eyes, antennæ, and wings. Compare its mouth parts with those of the locust. See Comstock's "Manual for the Study of Insects" for the mouth parts of a dipterous insect. To what branch does the mosquito belong? To what class, order, genus, and species does the common mosquito belong.

For information on the mosquitoes and their relation to malaria and yellow fever, see Dr. L. O. Howard's book on mosquitoes.

XX. — The Perch

Materials. — A perch, black bass, or sunfish, live goldfish, dissecting pans, scalpel, scissors, and piece of bread.

Directions. — (Although this exercise pertains especially to the perch, the black bass, sunfish, or any other common fish will do with very little modification of the outline. Small fish, such as minnows, may easily be obtained from streams and permanent pools and placed in aquaria for observation. In large towns and cities it is often possible to have living goldfish in glass aquaria.)

A. Study of a Living Fish. What is the form of the body? Is the form of the fish adapted to its life in the water? Is the tail symmetrical? That is, is the dorsal lobe of the same shape and size as the ventral one?

How many fins has the goldfish? Where are they located? How many single fins are there? Are any of them in pairs? Watch the fish swim. What is the principal organ of locomotion? Which fin is used most in swimming? Catch the fish carefully and place a light rub-

ber band about the anterior (pectoral) pair of fins and watch the result. Catch it once more and put the band about the posterior (pelvic) pair of fins and watch the result. After these experiments what can you say regarding the functions of the different fins? Which fins are used to maintain an equilibrium of the body?

Watch the movements of the mouth and gill covers. In what order do the movements follow each other? What is the reason for these rhythmic orderly movements?

Watch the eyes. Are they capable of movement? Do the eyes move together? Are the eyes furnished with lids? Do they seem to have any means of protection? Determine, if possible, the extent of vision.

Place some food on the surface of the water. Watch the fish obtain and swallow this food. Scatter small pieces of paper on the water. Does the fish swim for them? Upon what sense does it seem to depend to find its food? Does it eat the paper? Does it seem to have the sense of taste?

B. EXTERNAL FEATURES OF A FISH (perch). Note the shape of the body from a dorsal and side view. What can be said of its adaptation to swimming through the water? The body is flattened from side to side or *compressed*. Like the earthworm, the perch is bilaterally symmetrical.

Note the number, situation, size, and shape of the fins. How many are in pairs? Where are the pairs borne? How many are borne singly? Are these in the middle line of the body? How many dorsal fins are there? The front pair of fins is known as the *pectoral fins* and they correspond to the front pair of limbs in the higher animals. The more posterior pair are the *pelvic fins*. The single fin just back of the anal opening is the *anal fin*.

Study carefully the two dorsal fins. The spines of one are sharp, stiff, and unjointed, while the spines of the other are branched at the ends and are jointed, therefore flexible. Determine which fin has the stiff rays and which the soft ones. The membrane connecting the rays is really double, for it is simply a fold of the skin.

Observe the tail fin. Is it symmetrical? It is known as a *homocercal fin* because its lobes are equal and the backbone does not extend into it but stops at its base.

Note the shape and position of the eyes. Note the absence of eyelids and the transparent membrane, *cornea*, covering the eyes for protection. Note the dark central pupil and the colored circle surrounding it, the *iris*.

Note the nostrils in front of each eye. The posterior nostril is different in shape from the anterior one. Determine, by probing them with a bristle, if they open into the mouth.

Note that the body is covered with a thin, slimy skin, the *epidermis*. Underneath this are the scales. Note their arrangement. Find a place on the body where there are no scales. Remove a scale, being sure to observe which is the free and which the attached ends. Place it under the low-power objective and make a drawing of it to show its shape and the difference between the free and attached ends. A scale with the posterior edge toothed is a *ctenoid* scale. Are the scales of the perch ctenoid?

Note the line running from tail to gill cover along the side of the perch. This is the lateral line. Examine some of the scales in this line and determine how the line is produced.

The large flap on the side of the head is the *operculum*, or *gill cover*. The opening beneath the gill cover is the gill opening. The operculum is composed of several pieces

called *opercles.* How many are there? Along the lower and posterior edge of the operculum is a membrane supported by seven parallel rays. This is the *branchiostegal membrane* and *rays.*

Make a drawing of a side view of the perch, showing all the foregoing points possible.

Raise one of the gill covers and note the position of the gills. How many are there? Open the mouth widely and depress the tongue to determine the connection between the gill cavity and the mouth. Remove most of the gill cover. Note that each gill consists of a *bony arch* with comblike filaments on the posterior edge and teethlike organs, the gill rakers, on the anterior edge. The slits between the gills are the gill clefts. How many gill clefts are there?

Draw a complete gill, showing arch, filaments, and rakers.

Again open the mouth wide and note its size. Note the flat, short tongue. Find the teeth on the upper and lower jaws. What shape and size are they? Which way do they point? What purpose would they seem to serve, judging from their size and the way they point?

C. INTERNAL ORGANS. Make a shallow incision from just in front of the anal opening along the ventral wall of the abdomen through the tip of the lower jaw, being careful not to cut into the internal organs. Now make a deep cut with the scalpel along the lateral line on the left side from behind forwards and then remove one whole side of the abdomen being very careful not to injure the air bladder.

Note the spinal column along the dorsal side of the abdominal cavity. The liver, intestines, and other organs lie in the lower part of the abdominal cavity, while the thin air bladder lies in the upper part and its ventral wall forms a wall across the body cavity.

Note the shining membrane lining the abdominal cavity. This is the *peritoneum*. Note that there is another cavity between the gill covers which is separated from the abdominal cavity by a thin transverse partition, the *false diaphragm*. This anterior cavity is the *pericardial cavity*, and contains the heart.

The air bladder is the largest organ in the abdominal cavity. How much space does it occupy? Find the pinkish or brownish liver in the anterior part of the abdominal cavity. Tear it free and turn anteriorly. A rather large sac, the *stomach*, will then be seen. Pass a probe down the gullet into the stomach. Note that the stomach ends blindly at its posterior end and that the intestine branches off near the anterior end. Note several long, cylindrical appendages, the *pyloric cæca*, arising from the intestine a little ways from its origin at the stomach. Trace the intestine among the masses of fat and find that it is coiled in its anterior part and extends to the anus.

Find the greenish bile sac on the posterior surface of the liver.

The spermaries of the male are white and in the breeding season appear as long white bodies running toward the anterior part of the abdominal cavity, just under the air bladder. The ovary is an elongated sac lying in a corresponding position in the female.

A small pink or green sac, the urinary bladder, lies just posterior to the oviduct.

If a fresh fish is being dissected, examine the air bladder. Note its thin walls. Puncture it. What is the result? Determine if there are any blood vessels in the walls of the air bladder.

Remove the air bladder and observe the dark red kidneys extending closely along the dorsal side of the abdominal cavity, one on each side of the backbone. Just above the gullet, in the pericardial cavity, the kidneys unite and form a median, large, and dark colored mass, the *head kidney*. Find this mass.

Find the heart again and examine it. Of how many parts does it seem to consist? The large vessel lying across the posterior end of the pericardial cavity is the *sinus venosus*. The irregular, darker portion lying below and slightly in front of the sinus venosus is the *auricle*. The rounded, bulblike *ventricle* lies below and at the side of the auricle. The ventricle sends the blood forward into the *arterial bulb* which lies just in front of the former. From the latter, the *aorta* carries the blood directly to the gills.

D. Topics for Further Study. If a young shark is at hand, compare it with the perch as to scales, gill slits, operculum, situation of the mouth, etc. Study the fisheries of the United States from reports of the Bureau of Fisheries. Study the food of the fresh-water fishes.

XXI. — The Frog

Materials. — Living and preserved specimens of frogs, tub or aquaria, wire netting, flies, thin board or shingle, towel, tape, tacks, thread, compound microscope, cover glasses, bristles, dissecting instruments, dissecting pan, pins; live frog's eggs, shallow pans, pond scum, mud, rocks, etc.

Directions. — (The common leopard frog, the green frog, or the bullfrog will serve equally well for the following outline. If desired, the specimens may be preserved in a five per cent solution of formalin while the dissection is going on.)

A. Study of a Living Frog. Put a live frog in a large tub or in an aquarium and watch it swim. What legs are used in swimming? Watch the movements of these legs. Do the front legs perform any active function in swimming? What position does the frog assume when it is quietly resting? Where does it rest? How long can it stay below the surface? How are the hind legs held when it is quiet? Why is the head held out of the water? Find the nostrils near the tip of the nose, one on each side. Notice the sort of rhythmic movements of the openings to the nostrils.

Put some wire netting over the tub and imprison living house flies beneath it. Determine, if possible, how the frog eats.

Put the frog on the floor for a little time and observe its method of locomotion under these conditions.

Determine how this animal breathes. Observe the nostrils, mouth, and abdomen, and describe the movements of each.

Make a drawing of a living frog in its sitting posture.

B. External Features. Note the short, wide, hump-backed body with the triangular head. Note the absence of fins, neck, and tail. How do these features compare with a fish?

How do the hind legs of the frog compare with the front ones? How many toes on the hind and on the front feet? What is found between the hind toes? Note that each leg has three parts. The front leg is divided into arm, fore-arm, and hand; the hind leg into thigh, shank, and foot.

Make a drawing of a front and hind leg showing the parts.

Note the smooth, moist, scaleless skin and the markings on the body and legs. What color is the frog above? What color is it below? The color above usually accords

with the surroundings of this animal and makes it less conspicuous to its enemies.

How many eyes has the frog, and where are they situated? Note how they protrude. Touch one of them with a pencil. Is the eye withdrawn? Note that it drops downward and inward. Determine the number of lids. Which is the thinner and capable of more movement? The under one is sometimes called the nictitating membrane.

Just behind each eye find the tympanic membranes of the ears. Note the white spot in the center of each. This is the place of attachment of the columella (see text, page 230).

Note the wide, capacious mouth and the fleshy lips bordering the jaws.

Circulation of the blood in the web of the hind foot. — Procure a thin board or shingle five or six inches long and near the middle of one end cut a V-shaped opening about the size of the expanded web. Wrap the frog in a wet towel or cloth with a hind foot protruding, and, with tape, tie the animal firmly but not too tightly to the board. Do not tear the web, but stretch it carefully over the opening by attaching threads to the outside toes and tying them to tacks stuck in the board. Then place the whole firmly on the stage of a microscope and examine the web with the low-power objective.

Note the network of blood vessels in the web. The larger vessels running mainly toward the free ends of the web, and constantly diminishing in size by subdivision, are the *arteries*. They gradually break up into *capillaries*. The capillaries unite and form large vessels, the *veins*.

Now place a cover glass on the web and run water beneath it. Examine the web with the high-power objective.

Determine the direction of the blood flow by the movements of the bodies (the corpuscles) floating in the blood.

There are two kinds of corpuscles in the blood, the red ones and the white, or colorless ones. What is the shape of a red corpuscle? The red ones, for the most part, are in the middle of the currents while the white ones are along the edges of the streams. Note that the red ones change shape sometimes when crowded or pressed. Do they resume their original shapes?

Make drawings of the two kinds of corpuscles.

C. INTERNAL FEATURES. Examine the mouth and note the number and arrangement of the teeth on the upper jaw and the absence of teeth from the lower jaw. Look on the roof of the mouth for a patch of teeth.

Note the long fleshy tongue. Draw it forward and determine how it is attached to the mouth. Note the sticky saliva on the tongue. Probably the manner in which this animal procures food has already been determined. If not, try again, or get a toad and confine it in a box containing some moist earth and feed it with flies, beetles, etc. The toad obtains its food in a manner similar to that of the frog, is much more at home in captivity, and can more easily be observed.

In the back part of the floor of the mouth note the glottis, the slitlike opening to the windpipe.

Push a bristle down the nostrils, to determine where they enter the mouth.

Make an opening in the tympanic membrane and push a bristle through the cavity of the internal ear into the mouth. The tube through which the bristle enters the mouth is the *Eustachian tube.*

Dissect the frog under water in the pan. Lay the body on its back, stretch out the legs and pin them down. Then cut through the skin on the median line of the ventral surface from the lower jaw to the posterior end of the body. Make a transverse cut across the middle and turn back the four flaps and pin them down. If the skin has been carefully cut, the thin abdominal wall will now appear unharmed. Note a dark vein along the median line showing through the wall. Cut through the wall to one side of the vein so as not to injure it, and continue the slit to the breastbone. Raise the breastbone and see the heart. Then cut through this bone a little to one side, and pin the flaps of the abdominal wall out of the way to expose the internal organs.

The most conspicuous organ is the reddish liver. How many lobes has it? Find the gall bladder, a dark, spherical sac, on the under side of the liver. Trace its connection with the intestine.

Circulatory organs. — Just in front of the liver is the heart, inclosed in a thin, transparent sac, the *pericardium.* Pinch up the loose pericardium and cut through it, being careful not to sever any of the blood vessels, and remove as much of it as possible. Note the heart inside, with two auricles at the base and the single ventricle at the posterior end. If the heart is still beating, it may be possible to time its pulsations.

Note the large artery that springs from the anterior end of the ventricle. It soon divides into two main arteries, each of which then divides into three others, called the *aortic arches.* The anterior arch carries blood to the head; the middle arch carries blood to various parts of the body; while the posterior arch conveys blood to the lungs and skin for aeration.

Make a diagrammatic drawing of the heart and its arteries.

Digestive organs.— Push a long probe through the pharynx and gullet into the stomach. What is the shape of the stomach? How large is it?

The intestine begins at the posterior end of the stomach. Trace its turns and windings to the enlarged posterior portion, the *cloaca*. How is the intestine held in place? From what is it suspended? The thin tissue supporting the intestine is called the *mesentery*.

The liver has been already described.

The pancreas is a whitish, compact organ lying between the stomach and intestine.

Make a diagram of the alimentary canal.

Respiratory organs. — Find the glottis and inflate the lungs. They are usually concealed by the liver. How many lobes to the lungs? What color are they? Dissect out the windpipe and trace it to the mouth.

Excretory organs. — There are two reddish brown kidneys on the dorsal side of the body cavity near the cloaca. In the extreme posterior end of the body cavity will be found the urinary bladder. It is a thin sac and is usually empty.

D. DEVELOPMENT AND LIFE HISTORY. The eggs of the frog are laid in large, irregular, jellylike masses in spring, in the shallower parts of ponds and streams near the shore. They may be gathered and brought to the laboratory in water. Place some of them in a large tin milk pan. Tilt the pan by placing something under one edge, and put in enough water to cover the bottom an inch deep in the shallower part. It would be well to siphon this water out occasionally and put in some fresh. Gather some mud, pond scum, rocks, and leaves with fine slimy sediment on

them from the pond and put them in the pan. This material will furnish food for the young tadpoles. New food should be added from time to time. Do not attempt to rear too many in one pan, and do not set the pan in strong sunlight. Arrange other pans and experiment with them by setting them in light of varying intensity and in temperatures of different degrees.

Note the shape and color of the eggs. Note when the eggs hatch. Note the appearance of the very young tadpoles. Do they possess feet? How do they swim? Do they ever fasten themselves to objects in the water? What color are they? Observe them from day to day and note all the changes that take place in them as they grow. How do the young tadpoles breathe? Find the gills. Where are they? Determine, if possible, when the gills disappear. Note that the young tadpole, as it grows older, begins to come to the surface now and then to get air. The tadpole is now beginning to use its lungs. Note the first appearance of the legs. Which pair appears first? Observe the tail from day to day. Note that it grows smaller and smaller. It is actually absorbed into the body. Note when the second pair of legs appear. Note the time that it takes a young tadpole to become mature.

It would be well to make careful notes and even drawings from time to time.

In the same manner the life history of the toad may be easily followed.

XXII. — The Lizard

Materials. — Specimens of lizards, wooden box, earth, leaves, wire netting, dissecting instruments, board, tacks, inflating apparatus (see Appendix).

Directions. — (Although the six-lined lizard was used in making the following outline, any one of three or four species will serve quite as well.)

A. Haunts and Habits of Lizards. Lizards are common in the woods, around old logs, along rail fences, and about old stumps and brush piles. Some of them are swift of movement, and quickly scurry out of sight. Others climb trees and remain hidden among the leaves and branches. Some can change color to suit the environment, and some of them resemble the bark of trees upon which they live.

B. Study of a Living Lizard. Put a lizard in a box containing some moist earth, leaves, and a piece of wood beneath which it may hide. Cover with wire netting. If it is desired, the wire netting may be removed when the animal is under observation.

Study its mode of locomotion and rate of movement. See if it can climb a sharply inclined, smooth surface. Try it on a rough surface like the trunk of a tree or piece of branch with rough bark. Test its sight. Is its vision keen? Offer it some living flies, beetles, bugs, etc. How does it catch and eat them? Does it eat many? What can be said of its economic value in destroying injurious insects?

Offer it water and try and determine whether it drinks or not. If it does drink, determine the manner in which this is done.

Determine the number of eyelids. Thrust a pencil toward the eye and observe the movements of the *nictitating membrane* which can be drawn over the whole eye. This membrane comes out from the inner corner of the eye, where it lies folded when not in use.

Watch the animal breathe. How frequent are the respirations? Describe the breathing movements.

C. External Features. Note the four divisions of the body, — head, neck, trunk, and tail. How does this body division differ from the frog's?

Note the number of legs and compare them with those of the frog. How do the hind legs of the lizard compare in size with the front ones?

The fore legs arise behind the neck, and each one consists of the upper arm, the forearm, and hand, which has five fingers. Make out these parts.

The hind legs also consist of three parts, — thigh, shank, and foot. How many claws on each foot? Is there any difference in the length of these claws? Note the situation of the "big-toe" claw. The hind legs arise from the trunk more ventrally than the front ones.

Make a drawing of a hind leg showing all the parts.

What is the color of the body above and below? How many lines are on the body? Where are they situated?

Note that the body is covered with scales. How does this feature compare with the frog? Study the shape and arrangement of the scales on the head, back, tail, and belly. How many longitudinal rows of scales on the ventral surface? On some species the scales are not in longitudinal rows on this surface.

Note that the mouth is wide but that the jaws are not dilatable like those of the snake. Find the nostrils on the sides of the end of the head. They open into the mouth.

Back of the corners of the mouth note the *tympanums* of the ears. They are plainly visible.

The upper and lower jaws are each furnished with a row of small, conical teeth.

Note the tongue. Is it attached like the tongue of a frog? Observe the forked extremity of the tongue.

D. Internal Features. Lay the lizard on its back on a pine board and stretch the legs to the right and left and tack them to the board. Also put a tack through the tail and through the upper jaw, leaving the lower jaw free.

Seize the lower jaw and pull it upward to show the size of the mouth opening. Find the teeth on the jaws and determine the shape and size. Note the size, shape, and attachment of the tongue again.

At the root of the tongue find a small opening, the *glottis*. This is the entrance to the windpipe that leads to the lungs.

Begin immediately back of the fore legs and cut through the floor of the abdomen in a median line to the anal aperture. Be careful not to injure any of the internal organs. Now make a transverse cut just behind the front legs and turn the walls of the abdomen to the right and left and pin or tack down to the board.

Respiratory apparatus. — Use the inflating apparatus described in the Appendix and insert the point into the glottis, and inflate the lungs. Trace the windpipe to the lungs. Note that it bifurcates, a branch going to each of the lobes of the lungs. What is the shape and color of the lobes? How far back does each lobe extend?

Circulatory organs. — Note the heart on top of the windpipe and lungs. Of course, in the natural position of the animal, the heart would be ventrad of these organs. The heart is inclosed in a thin sac, the *pericardium*. Pinch up a fold of this sac, cut through it, and remove the heart, being careful not to sever any of the blood vessels. Note

that the heart consists of two auricles with a muscular ventricle between and behind them.

From the anterior end of the ventricle arise three arteries rather closely bound together. One, the *pulmonary artery*, goes to the lungs. The other two, *right and left aortic arteries*, send branches to the head, trunk, tail, and other parts of the body.

Find several veins, darker in color than the arteries, that lead to the heart.

The digestive organs. — Clear away any masses of fat that may be in the posterior part of the body. Begin at the mouth and trace the alimentary canal, noting the following parts: —

A gullet leading to the stomach.

The stomach quite a little wider than the gullet and with hard, muscular walls.

Following the stomach, the small intestine, or duodenum, which is more or less coiled.

The duodenum is succeeded by the large intestine, or rectum, which often contains undigested matter.

At the point of union between the small and large intestine, the latter is produced into a short, blind sac, the *cæcum*.

The rectum joins the cloaca, the dilated posterior end of the alimentary canal.

The liver is large and divided into a right and left lobe. It lies in the anterior part of the body cavity, and has a gall bladder which connects through a duct with the duodenum.

The pancreas is situated in the loop between the stomach and small intestine.

Make a diagram of the digestive organs.

Excretory organs. — Note the two dark red kidneys lying

in the posterior part of the body cavity, and in close contact with the dorsal wall. Each one opens into the cloaca through a delicate duct, the ureter. A urinary bladder opens into the cloaca on its ventral side.

Reproductive organs. — Find the two ovaries of the female that lie anterior to the kidneys. They are irregular, oval bodies, with their surfaces raised up into rounded elevation, showing the position of the ova. The oviducts are wide tubes that open into the body cavity at their anterior ends, while their posterior ends open into the cloaca just in front of the ureters.

The two spermaries of the male are white oval bodies in about the same position as the ovaries. The sperm ducts open into the ureters.

XXIII.—THE ENGLISH SPARROW

Materials. — Specimens of English sparrows, cotton, chloroform, pine board, tacks, dissecting instruments, pins, apparatus for inflating (see Ex. XXI).

Directions. — (Since these birds have become a pest, no compunction will be felt in killing what are needed for this work. It will be best to catch them alive.)

A. EXTERNAL FEATURES. Note the shape of its body. Is the body divided into the same parts as that of a frog or lizard? How many legs has the sparrow? How do they differ from those of the frog? How does the anterior pair of appendages differ from the fore legs of a frog? It must be remembered that these are homologous organs. What is the body covered with? Are the feathers of uniform thickness all over the body?

Note the shape of the wing. Note that they are attached

to the dorsal side of the body so that in flight the body hangs suspended. Find three principal joints in the wing. Note the long quill feathers in each wing and in the tail. Allow a bird to fly about the room and observe the movements of the wings. Also note that the tail is used as a rudder in guiding the bird, and as an aid in alighting.

Note that the head is prolonged into a horny beak, composed of the upper and lower mandibles. At the base of the upper mandible are the nostrils. Note where they open into the mouth. Note the bristles hanging at the corners of the mouth. These are the *rectal bristles*.

Note the large eyes. How many eyelids have they? Note the membrane that can be drawn wholly over the eye. This is the *nictitating membrane*.

(Some of the above features can be best observed on a dead bird. When necessary kill the bird by holding a piece of cotton saturated with chloroform to its nostrils.)

Below and behind the eye, look for the ears. They are hidden by the feathers. There are no external ears, but the auditory openings may be found. The feathers over the openings are not so compact as elsewhere. Why?

Feathers. — Examine a feather in detail. Note the *shaft* running through the center. The lower, transparent, hollow part is the *quill*. It extends only to the wide, expanded portion, the *vane*. The remaining part of the shaft, in the middle of the vane, is the *rachis*. Note that the rachis is opaque and solid. In the lower end of the quill, note an opening. A small conical projection of the skin fits into this opening, when the feather is attached to the body. Observe the vane closely. It is made up of narrow, linear plates, running out to the right and left from the rachis. These are the *barbs*. The barbs are fringed with similar

but smaller bodies. These are the *barbules*. The barbules interlock by means of very small hooks, thus forming a continuous sheet. The feathers that overlie the body and form the contour of the body are called the *contour* feathers. Pull off the contour feathers on a small space and note the *down* feathers. There are also other hairlike feathers that may be exposed, called *filoplumules*. They are seen on a chicken before it is singed. Separate the feathers above the base of the tail and find the *oil gland*.

Observe that the feathers extend down the leg over the knee, leaving only the ankle exposed. How many toes has a sparrow? It is a perching bird, so note the arrangement of the toes.

B. INTERNAL FEATURES. Lay the bird on its back on a pine board, stretch the wings and legs out, and tack them to the board. Part the feathers and, with a pair of scissors, cut just through the skin along the middle line from the tail to the base of the lower mandible. Work the cut edges of the skin loose from the sides of the body, and pin out of the way. Note the edge of the breastbone, or *sternum*, in the middle line. Note on each side the *large pectoral muscles* that move the wings. It is these muscles that furnish the white meat, or breast, of a turkey or chicken. Where are the largest muscles in a frog? Why?

Cut away all the breast muscles. Note the *lateral ribs* attached to the sternum. Note the *wishbone* in front of the sternum. It is made up of the two collar bones, *clavicles*, grown together at their inner ends. Note the *coracoid* bones extending from the anterior end of the sternum. Remove the wishbone and coracoid bones, cut away the abdominal wall, and cut the ribs from the sternum on each side and remove the sternum entirely. At the base of the

tongue, find the *U-shaped hyoid* bone surrounding the front of the *glottis*.

Respiratory organs. — The glottis opens into the *larynx*, a slightly swollen chamber. From the larynx, the *trachea* extends posteriorly, until it branches into two small tubes, the *bronchi*. At the union of the bronchi and trachea is a swollen portion, the *syrinx*. It has cords stretched across the inside. This is the song box of the bird. Trace the bronchi to the *lungs*. Inflate the lungs through the glottis, and note the large *air sacs* in the abdomen that are connected with the lungs.

In observing the lungs, the viscera had probably to be pushed aside. Allow them to return to place. Note the *heart*, with the large blood vessels leading from it. Do not cut them yet. Dissect out and remove the trachea and anterior ends of the bronchial tubes.

Digestive organs. — Note the *gullet* beneath the trachea. In the middle of the gullet is an enlargement forming the *crop*. Inflate the gullet to show the crop. The gullet, after leaving the crop, soon enters the *stomach*, which is difficult to find because it is scarcely larger than the gullet itself. The stomach, however, ends at the *gizzard*, which is a thick-walled organ for grinding the food. Find the gizzard. The *intestine* starts from the posterior end of the gizzard and immediately forms a loop which is known as the *duodenum*. Within the loop forming the duodenum is a pinkish gland, the *pancreas*. Behind the heart is the large, brownish *liver* that empties its *bile* into the duodenum. The intestine is considerably widened at the posterior end. This widened portion is the *cloaca*. On each side of the intestine near the end is a blind sac. These are called the *cæca*.

Circulatory organs. — Cut the sac about the heart. It is called the *pericardium*. What is the shape of the heart? The heart has four chambers, like that of the mammals. Snip off the posterior end of the heart and note that the *ventricles* are distinct. The *auricles* are situated at the anterior end of the heart. The sparrow, therefore, has a double circulation.

Note the large artery coming off from the left ventricle. This is the *aorta*. Note that it soon gives off two branches, the *innominate arteries*. Each of these divide into three smaller arteries. The aorta runs along the back toward the posterior end of the body. The right ventricle is connected directly with the lungs by the *right* and *left pulmonary arteries*. The blood is brought back to the left auricle by the *right* and *left pulmonary veins*. The blood system may be injected and studied in detail. For directions, see Needham's "Lessons in Zoölogy" or Parker's "Zoötomy."

Excretory and reproductive organs. — Look in the body cavity, near the backbone, in the posterior part of the body for the *kidneys*. They are three-lobed, and have two tubes, the *ureters*, running from them to the cloaca. The kidneys are partly hidden by the reproductive organs. In the male, the latter consist of a pair of roundish, or oval, light-colored *testes*. In the female, they consist of a large *ovary*, sometimes containing the half-formed eggs.

Examine the bones of the sparrow and see if they are hollow.

C. Field Study of the Sparrow. Very interesting field studies may be carried on in connection with this bird. Observe it in its natural haunts. Is it social or solitary? What does it eat? Can it sing? Can it hear? Can it see well? How does it behave toward other birds?

From a study of its food would you judge it to be helpful or injurious to the farmer? Where does it build its nest? Of what material is it built? When is the nest made? How many eggs are laid? When do they hatch? Are the young birds helpless? What do the young birds eat? Is there more than one brood of young in a season?

D. TOPICS FOR FURTHER STUDY. Write out the chief characteristics of the sparrow. Write a summary of the changes through which the food goes in its passage along the alimentary canal. Write a summary of the circulation of the blood, tracing its route, step by step, beginning at the left auricle. Sum up the processes of respiration, describing the organs concerned. Name and describe the organs of excretion, giving the particular function of each.

XXIV. — THE GRAY RABBIT, OR COTTON TAIL

Materials. — Specimens of rabbits, dissecting board, dissecting instruments, alcohol.

Directions. — (The wood rabbit, gray rabbit, or cotton tail, is found North and South and East and West. It can be easily trapped in a box trap, and serves well as a typical mammal. If desired, a cat may be used instead.)

A. EXTERNAL FEATURES. Note the body covered with hair. Note the thick, soft fur next to the body, with long stiff hairs tipped with black sticking up through the fur. Note the stiff, bristlelike hairs above and below the eyes, and on each side of the mouth. Examine the soles of the feet. Are they smooth or hairy? Note the long ears. How are they held in life? Note the eyes wide apart. Note the cleft upper lip. Are the legs all of the same length? Which are longer and why? How does a rabbit travel?

Note the tail. Now does it compare with that of a cat? What color is the tail? What color is found on the breast beneath the head?

B. INTERNAL FEATURES. In dissecting the rabbit, it is best to lay it upon a flat board somewhat longer than the animal. In examining the head, it is best to remove the skin entirely. To do this, cut through the skin around the neck and pull it off over the head wrong side out, cutting carefully where needed.

Head. — Note the cartilages at the bases of the ears, that support them, and also the muscles that move the ears. Cut off the ears and note the auditory canal that leads into the head.

After the skin is removed begin at the corner of the mouth and cut through the cheek in a posterior direction, severing the lower jaw from the upper where it is hinged, and then forcibly turn that half, or ramus, of the lower jaw, breaking its connection in front. This will lay open the mouth cavity.

Observe that there are two pairs of long curved teeth in front, the *incisors*, one pair on each jaw. How do they come together? Turn back the cut half of the lower jaw and observe this point. Are the edges sharp or dull? Note the pair of small incisors on the upper jaw just back of the large ones. What are the incisors for?

Note farther back, the *molars*. How many pairs above and below? How do these meet? Are the surfaces smooth and are they flat or chisel-edged? Note the space without teeth between the incisors and molars. What teeth occupy this space in your own mouth?

Note the tongue. What shape is it? Where is it fastened to the mouth? Is it thick or thin? Is there any

difference in the softness and roughness of the anterior and posterior part of the tongue? The free anterior part has taste papillæ on its surface. On the posterior part of the tongue are four large papillæ arranged transversely across the tongue in a curved line.

The middle part of the roof of the mouth is termed the *palate.* The anterior portion has transverse ridges, and is hard, hence is called the *hard palate.* The posterior portion is without ridges and is soft, hence is called the *soft palate.* Note that the soft palate terminates in a free pendulous flap. Just above the free end of the soft palate find the nasal opening, or chamber. Now cut away the soft palate and find the two tubes, *Eustachian tubes,* that lead from the ears into the nasal chamber, one on each side.

There are also ducts from four pairs of salivary glands entering the mouth. If possible, find these glands and their ducts.

The *parotid gland* lies just below and in front of the external auditory canal. The duct leading from it passes anteriorly, and opens on the inside of the cheek opposite the second upper molar tooth.

The two *submaxillary glands* lie between the angles of the lower jaw. Their ducts open on the floor of the mouth beneath the tongue, about half way between the base of the tongue and the lower incisors, and near the median line.

The *sublingual gland* lies on the inside of the mandible a little anterior to the base of the tongue. It is small, and its duct is difficult to find, but opens under the tongue.

The *infraorbital gland* lies just below and in front of the eye. Its duct passes downward to the cheek, and opens near that of the parotid gland.

The mouth is continued posteriorly by a funnel-shaped chamber, the *pharynx.* The small end of the pharynx leads directly into the *gullet,* or *esophagus.* In the floor of the pharynx, just before reaching the gullet, is an opening, the *glottis,* which leads into the windpipe. The glottis is guarded by an erect flap of cartilage, the *epiglottis.* The epiglottis is raised when the animal breathes, but is closed down when food is swallowed so that it can pass directly on into the gullet.

Body. — The legs must now be fastened down. Extend the hind ones backward and the front ones forward, with the rabbit on its back, and tack them to the board. Slit the skin from front to rear, peal it off, and turn to the sides out of the way. Note the ribs in front, inclosing the *thorax;* also the soft abdomen to the rear of the thorax. Cut the ribs off along each side of the animal, and remove them entirely, thus exposing the cavity of the thorax, being careful to injure none of the contained organs.

Note the *diaphragm,* a thin muscular partition dividing the thorax from the abdomen. What is its shape? Which cavity is the concave side toward, and which the convex side? Note the *liver* close against the posterior side of the diaphragm. Note the *lungs* in the thorax on the anterior side of the diaphragm. What color are they? Lift them in the hand. Are they light or heavy? Why? They are commonly called "lights." What lies between the lungs? What is the shape of the heart? Which way does its small end point? The heart lies within a membranous pouch called the *pericardium.* Note that the cavity of the thorax is lined with a thin, delicate membrane known as the *pleura.*

Return to the gullet and follow it to the *stomach.* What shape is the stomach? How does it lie? Estimate the

amount it will hold. What leaves the stomach at the end opposite the gullet? The first part of the intestine, beginning at the stomach, is the *duodenum*. This is folded upon itself forming a long narrow loop. The opening of the stomach into the duodenum is guarded by a valve, the *pylorus*, which prevents food from leaving the stomach until it has been properly acted upon. The ducts from the *gall bladder* and *pancreas* enter the duodenum. Find the *gall bladder* beneath one of the lobes of the liver. The *pancreas* is a whitish mass in the loop of the duodenum. Lying behind the stomach is a large, flat, dark red gland, the *spleen*.

Following the duodenum is the small intestine which is much folded. To complete the alimentary canal is the large intestine. Where the large and small intestines join is a large pouch that takes up considerable room in the abdominal cavity. In fact, it is the most conspicuous part of the alimentary canal. This is the *cæcum*. It ends in a fingerlike process known as the *vermiform appendix*, which, in man, is often the seat of the disease known as *appendicitis*.

Note the bean-shaped *kidneys* attached to the dorsal side of the abdominal cavity. Note a long, white duct, the *ureter*, passing downward from each kidney to the *bladder*, which lies ventral to the large intestine.

Begin again at the glottis. Just below is the *larynx*, the voice chamber. From this leads the *windpipe*, or *trachea*. Note the cartilaginous rings about the trachea. Note that the trachea soon divides into two tubes, the *bronchi*. Note that one passes to the root of each lung. Cut the larynx open and find the vocal cords.

The heart and circulation are very similar to those of the sparrow, and the directions given there will suffice for the rabbit.

Skeleton and nervous system. — Dissect out carefully the backbone without breaking its connections anywhere, and clean it as well as possible. Examine the vertebræ and count them. There are five groups of vertebræ: the *neck* (cervical) *vertebræ;* the *chest* (thoracic) *vertebræ,* to which are attached the ribs; the *back* (lumbar) *vertebræ,* which have no ribs attached to them and are the largest of all; the *sacral vertebræ,* which are fused together; and the *tail* (caudal) *vertebræ.* How many vertebræ in each region? Note the soft, white cord running through the vertebræ. This is the *spinal cord.* Trace it to the head and determine its connection with the brain. Cut away the top of the skull and note the *brain.* Remove the brain carefully, cutting all the nerves, and place it in alcohol. Note that the brain and spinal cord occupy a cavity on the dorsal side of the animal. Remember that the other great cavity of the rabbit's body, composed of the thoracic and abdominal cavities, lies on the ventral side of the body.

Make a diagrammatic cross section of the body showing these cavities and their contents.

When removing the brain take great care and note the twelve pairs of cranial nerves that branch off from it. The brain is made up of the *cerebrum,* which consists of two large convoluted bodies, the *cerebral hemispheres;* the *olfactory lobes,* that lie in front of the cerebrum; the *cerebellum,* which lies posterior to the cerebral hemispheres on the dorsal side, and which consists of a large *central lobe,* two *oblique lateral lobes,* and a pair of small *flocular lobes* on the outer edges. Just behind the central lobe of the cerebellum is the *medulla.*

Appendages. — Compare the fore limbs of the rabbit with the wings of a sparrow. Note the difference in function and structure. Clean the feathers and flesh from the wing

and the hair and flesh from the leg, being careful to retain all the bones of each in their proper relations to each other.

Make a drawing of each organ, name the bones in each, and compare the structure of the two. How do they differ? How do they resemble each other? Note that the wing of a bird and the leg of a mammal are surprisingly alike. They are homologous organs.

If it is desired to make a more extended study of the nervous system and of the skeleton, consult Needham's "Lessons in Zoölogy" and Parker's "Zoötomy."

C. Topics for Further Study. Compare a diagrammatic cross section of the body of a rabbit with that of an earthworm. Show the differences and similarities. Sum up the chief characteristics of the rabbit. To what class does it belong? Give the chief characteristics of that class. Compare the rabbit with the sparrow, writing out, in parallel columns, the differences and similarities.

APPENDIX

In the laboratory exercises many directions were given for obtaining and treating the animals studied. But certain apparatus, reagents, and methods are demanded in the work that we could not speak of there. These we shall discuss briefly and simply in the following paragraphs.

Equipment. — For practical work in dissection, a well-lighted room, furnished with steady, flat-topped tables, from 28 to 30 inches high, is needed. For some of the work, compound microscopes (Fig. 1, page 6) are a necessity. Excellent ones can be bought for $25 or $30 apiece. If one or more of these cannot be had, some of the exercises must be omitted. Simple microscopes with simple lenses may be obtained at a small expense, and are a great aid. With the microscopes, should be provided glass slides, cover glasses, and watch crystals. Forceps with corrugated points and scissors with straight and curved points, should be accessible to the student, being furnished either by himself or by the school authorities. The student should also have a scalpel, paper of ribbon pins, and dissecting needles (Fig. 2). The dissecting needles may be made by forcing steel needles, head first, into the ends of neatly rounded pine sticks of appropriate size for handling. If possible, dissecting pans of good tin or galvanized iron, about 5 by 8 inches, and 2 inches deep, with flaring sides, should be provided for use in certain dissections. Across the pan, $\frac{1}{4}$ inch from the bottom, solder a wire, then run melted

paraffin into the pan until it stands ½ inch deep over the bottom. When it cools the wire will hold it in, and specimens may be pinned to it at will.

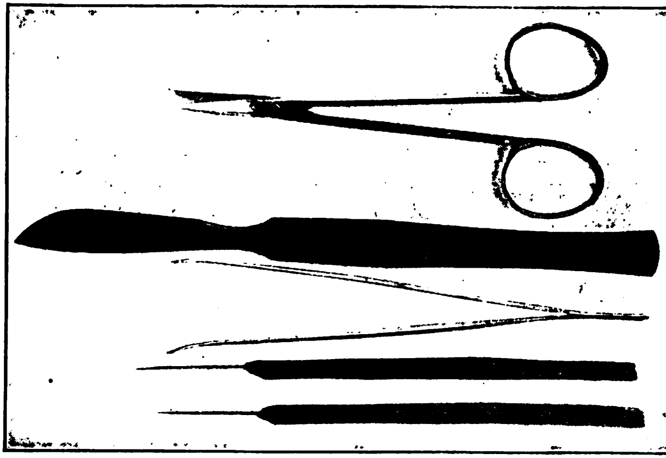

FIG. 2. — Dissecting Instruments.

REAGENTS. — A few reagents are necessary in preserving the specimens and for other purposes. Alcohol, 95 % and 85 %, and formalin, 4 %, are necessary for preserving specimens. 80 % and 85 % alcohol may be made from the 95 % alcohol by dilution with water. A normal salt solution (a ¾ % solution of salt in water) is useful in mounting specimens that might be destroyed by the osmotic power of water. Glycerin, for mounting objects temporarily; Canada balsam, for mounting hard objects; and 20 % nitric acid, for preparing tissues to dissect the nervous system, are also desirable. Methyl green is useful in staining fresh or preserved tissues. Dissolve it in water, using about as much powder as the water will dissolve, and add a few drops of acetic acid.

Dissections. — All dissections of small animals should be made in pans under water. The different specimens may be pinned out on the paraffin with ribbon pins. If the student is working on fresh specimens, and is not able to finish them in one day and wishes to keep them fresh, add several drops of carbolic acid to the water.

Injections.—Blood vascular and water vascular systems are more easily studied, if injected with a colored solution. The following solution is a good one: One part gelatin to four parts of water. Soak the gelatin thoroughly in the water, and add one part of a saturated solution of acetate of lead in water, and one part of a saturated solution of potassium bichromate. These are best mixed while hot, because the gelatin is then liquid. Filter the whole, hot, and inject the specimen while the mixture is warm. A syringe is necessary for the injection. Attach a piece of glass tubing drawn to a point to the end of the syringe by a rubber tube. There should be a constriction near the point of the glass tube, to afford an opportunity to tie an artery or vein to it. Several pieces of tubing should be made with different sized points to fit various sized organs. By removing the syringe, the remaining part of the apparatus will serve admirably to inflate the lungs, alimentary canal, etc., of the animals studied.

Preserving Specimens. — Ordinary specimens may be preserved for museum use in 85 % alcohol. Some may be well preserved in 4 % formalin. Certain preparations of the different organs of the body made during the progress of the work may be preserved in Fischer's solution. It is made as follows: 50 cc. of formalin, 15 g. of zinc chloride, 100 g. of sodium chloride (common salt), and 2000 cc. of water. Mix them until dissolved.

Preparing Skeletons. — If the pupils wish to study skeletons, they may be prepared as follows: Remove all skin, viscera, and flesh possible; boil the skeleton for 40 minutes in a soap solution, one part, and water four parts; boil again 30 minutes, in equal parts of the soap solution and water; rinse the bones in cool water, clean and dry them. The soap solution is made as follows: mix 200 cc. of water, 12 g. saltpeter, 75 g. hard, white soap, and heat until all is dissolved. Then add 150 cc. of strong ammonia.

Collecting and Rearing Insects. — Insects are the most convenient and easy to rear and observe of all animals. They can be studied with apparatus made at home with very little cost. If all the practical work in a course in zoölogy should be done with insects and birds very satisfactory results might be obtained, although such a course would be unbalanced. In discussing the subject of collecting and rearing insects, the author will quote freely from "Insect Life" by Professor J. H. Comstock.

The articles necessary in rearing and studying insects are a net, killing bottle, pins, cork, boxes, and aquarium jars.

Net. — Find a broom handle and make a groove, about 6 inches long and deep enough to receive a lead pencil, on each side of it at the larger end (Fig. 3, *a*). Then obtain a piece of No. 3 galvanized wire, 3 feet 6 inches long, and bend it in the form of a circle, leaving about 6 inches at each end bent back to be laid in the grooves on each side of the handle (Fig. 3 *b*). Wind spool wire closely and tightly about the stick over the ends of the wire, until securely fastened. Buy $\frac{1}{6}$ of a yard of heavy sheeting, and fold it over the wire ring double. Then, out of $\frac{3}{4}$ of a yard of cheese cloth, make a bag not quite as deep as your

arm is long and sew it to the piece of sheeting on the wire ring.

How to use the Net. — Most insects are quick of movement and do not remain still long at a time. To catch them, one must give quick, vigorous strokes with the

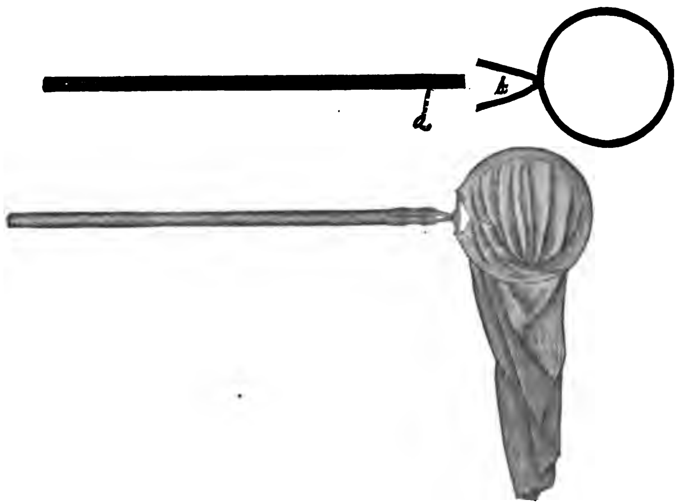

Fig. 3.— Insect net; *a*, groove in the handle to receive the ends of the wire, *b*. Below, the net is shown complete.

net. To keep the insect in the net when once caught, give the handle a quick turn to throw the lower part of the bag across the wire ring, thus closing the mouth of the net until ready to take out the insect. To sweep the grass for insects, grasp the handle of the net firmly in both hands and pass it quickly from right to left, over the grass, in front of yourself while walking. The same net may be used for dipping up aquatic insects, although it must be thoroughly dried before using again for general purposes.

Killing Bottle. — A wide-mouthed bottle is the first

requisite. A quinine bottle answers admirably (Fig. 4). A straight vial without a shoulder is convenient to carry in the vest pocket. In the bottom of the quinine bottle, put about a teaspoonful of cyanide of potassium (poisonous). Usually this material is in lumps. Pulverize, pour it into the bottle, and pack it down evenly with the flat end of a lead pencil. Pour on top of it enough dry plaster of Paris to cover it from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in depth. Pour just enough water — a few drops at a time — on the plaster to make it set on top. It can be smoothed and packed with a lead pencil. Do not wet the plaster all the way to the cyanide, else the cyanide will dissolve and make the bottle very moist and sticky, thus ruining the insects. If the bottle is too moist, put in circles of blotting paper. Leave the newly made bottle open over night, so that it will dry out. Then cork, and it is ready for use. If care is exercised to keep the bottle corked, it will last a whole season.

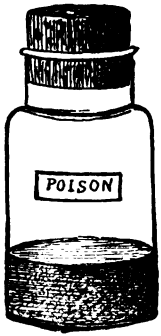

FIG. 4. — Killing bottle.

Another method of making a killing bottle is to pour $\frac{1}{2}$ inch of dry sawdust over the cyanide and force a circle of thick blotting paper into the bottle to hold the sawdust and cyanide in place. The circle of paper should be slightly larger than the inside of the bottle, that it may fit tightly. With this method the bottle may be used again and the cyanide renewed when it has lost its strength. Moreover, the bottle is much lighter than if plaster of Paris is used. Such a bottle has a disadvantage from the liability of the blotting paper to work loose and allow the sawdust and cyanide to mix up with the insects. The bottle should be

labeled poison, and care should be taken not to inhale the fumes that come from it, for they are deadly poison when inhaled in sufficient quantity. One will soon become expert in catching many insects in the bottle directly. Many insects may be caught by holding the bottle under them, when they are on flowers, for instance, and knocking them into the bottle with the cork, stopping the mouth quickly.

Fig. 5.—An insect properly pinned and labeled.

Pins.—Common pins are too thick and corrode too easily. It is best to buy German insect pins; they cost fifteen cents a hundred, or less if bought in larger quantities. Nos. 3 and 5 will be most used. For small insects, No. 1 is necessary. Pin insects, except beetles, down through the middle of the thorax (Fig. 5). Pin beetles through the right wing cover, just anterior to the middle of the body. Put a small label, containing the date and place of capture, on the pin below the insect's body. Many tiny insects must be glued to card points or impaled on the points of small pins, the larger ends of which, after the heads have been cut off, are stuck into small pieces of cork or blotting paper, which in turn are put on larger pins.

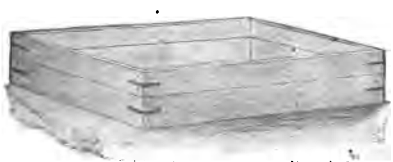

Fig. 6.—Insect box, made of wood, with glass top.

Boxes.—The pinned insects should be kept in boxes or

drawers that have bottoms lined with corn pith or sheet cork to receive the pins. Cigar boxes are good, but all boxes of that kind are loose and permit small insects to enter that live upon and destroy the pinned specimens. Tight boxes with glass covers made especially for the purpose are best for all permanent collections (Fig. 6). See "Insect Life," pp. 306–309, for directions for making these boxes. Two tablespoonfuls of carbon bisulphide may be poured into each box once a month to kill the pests.

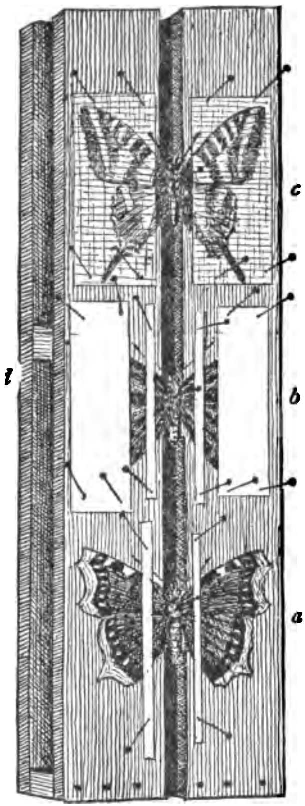

Fig 7.—Spreading board.

Butterflies and some other insects with large wings should have their wings spread while fresh, so that they will dry and remain in that position when pinned. A board for spreading insects is shown in Figure 7. For more detailed instructions, see "Insect Life," pp. 303–305.

Fig. 8. — Rearing cage, made of a flower pot and a lantern globe.

Cages. — A small rearing cage

may be made with a flower pot and lantern globe, as shown in Figure 8. Fill the pot with earth and sink a bottle in the earth up to its neck, in the center of the pot, to hold water-soaked sand in which to place the stems of the food plants. Tie mosquito netting over the mouth of the globe.

FIG. 9.—Battery jar aquarium.

"A good home-made cage can be built by fitting a pane of glass into one side of an empty soap box. A board 3 or 4 inches wide should be fastened below the glass so as to admit of a layer of soil being placed in the lower part of the cage, and the glass can be made to slide, and thus serve as a door. The glass should fit closely when shut to prevent the escape of insects."

"Many larvæ when full grown enter the ground to pass the pupal state; on this account a layer of loose soil should be kept in the bottom of a breeding cage. This soil should

not be allowed to become dry, neither should it be soaked with water." For further and full instructions, see "Insect Life," pp. 326–335.

AQUARIA. — For the breeding of aquatic insects aquaria are needed.

"Small aquaria can be made of jelly tumblers, glass finger bowls, and glass fruit jars, and larger aquaria can be obtained of dealers. A good substitute for these is what is known as the battery jar (Fig. 9). There are several sizes of these, which can be obtained of most dealers in scientific apparatus.

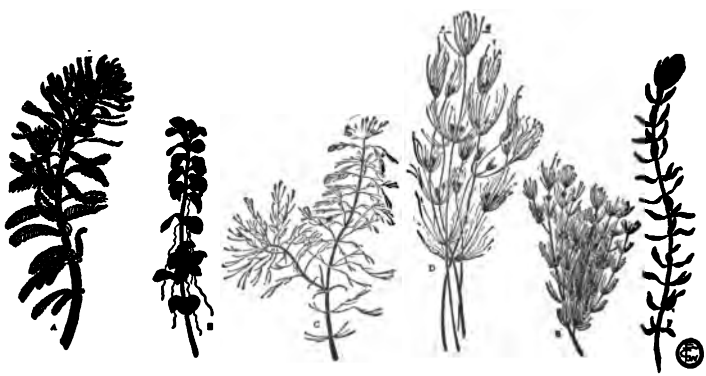

FIG. 10. — Plants for an aquarium; *a*, parrot's feather; *b*, water purslane; *c*, water starwort; *d*, *e*, stoneworts; *f*, waterweed,

"To prepare an aquarium, place in the jar a layer of sand; plant some water plants in this sand; cover the sand with a layer of gravel or small stones; and then add the required amount of water carefully, so as not to disturb the plants or to roil the water unduly. The growing plants will keep the water in good condition for aquatic animal life and render changing of the water unnecessary,

if the animals in it live naturally in quiet water. Among the more available plants for use in aquaria are the following (Fig. 10): —

" Waterweed, *Elodea canadensis;*

" Bladder wort, *Utricularia* (several species);

" Stoneworts, *Chara* and *Nitella* (several species of each);

" Water starwort, *Callitriche* (several species);

" Water cress, *Nasturtium officinale;*

" Frog spittle, or water silk, *Spirogyra;*

" A small quantity of duckweed, *Lemna,* placed on the surface of the water adds to the beauty of the aquarium."

BIRDS AND THEIR EGGS. — We do not believe in making collections of the skins and eggs of birds. We believe in studying birds in the green fields and wooded glens with a field glass and notebook. If a collection *must* be made for the school, consult Davie's " Methods in the Art of Taxidermy " and Bendire's " Directions for Collecting, Preparing, and Preserving Birds' Eggs and Nests."

Vertebrates and invertebrates, other than birds, mammals, and insects, may be preserved in 85% alcohol or 4% formalin, in glass jars, so that they may be examined without being handled. Jars for this purpose may be obtained of dealers in laboratory supplies. Fish had better be preserved in alcohol.

BOOKS. — There is no doubt that, in the study of nature, books are often used too much. Yet a temperate use of the right kind of books is a great inspiration. For example, the author believes that the fifteen minutes spent now and then in reading to a class short extracts from Kipling, Bullen, Burroughs, Sharp, and others have been very profitable minutes. There is no more interesting descrip-

tion extant of squid and cod fishing than in Kipling's "Captains Courageous." Better still is it for the pupils to read these books themselves. The author gives a list of books that may, if read at the proper times, impart life and enthusiasm to what might otherwise become a monotonous subject. First of all, however, we shall give a list of reference books that may well be in every school library.

BAILEY, F. MERRIAM. Handbook of Birds of the Western United States. Houghton, Mifflin, & Company, $3.50.

BEDDARD, F. E. Text-book of Zoögeography. G. P. Putnam's Sons, $1.50.

BENDIRE, CHARLES. Life Histories of North American Birds. Distributed by the Smithsonian Institution.

BENDIRE, CHARLES. Directions for Collecting, Preparing, and Preserving Birds' Eggs and Nests. Distributed by the United States National Museum.

CAMBRIDGE NATURAL HISTORY. Ten volumes, The Macmillan Company, about $3.50 a volume.

CHADBOURNE, P. A. Instinct in Animals and Men. G. P. Putnam's Sons, $2.50.

CHAPMAN, F. M. Handbook of Birds of Eastern North America. D. Appleton & Company, $3.00.

COMSTOCK, A. B. Hints for Collecting and Preserving Insects. Teacher's Leaflet No. 7. Bureau of Nature Study, Ithaca, N.Y.

COMSTOCK, J. H. Manual for the Study of Insects. Comstock Pub. Company, Ithaca, N.Y., $3.75.

COMSTOCK, J. H. Insect Life. D. Appleton & Company, $1.75.

COMSTOCK, J. H. AND A. B. How to Know the Butterflies. D. Appleton & Company, $2.25.

COUES, ELLIOT. Key to North American Birds. Dana Estes & Company, $12.50.

COWAN, T. W. Natural History of the Honey Bee. London, Houlston, 1*s*. 6*d*.

DAVIE, OLIVER. Methods in the Art of Taxidermy and Nests and Eggs of North American Birds. Columbus, Ohio, Oliver Davie & Company.

GAGE, S. H. Life History of the Toad. Leaflet No. 9. Bureau of Nature Study, Ithaca, N.Y.

HEILPRIN, A. Geographical and Geological Distribution of Animals. D. Appleton & Company, $2.00.

HOLLAND, W. J. The Moth Book. Doubleday, Page, & Company, $4.00.

HOLLAND, W. J. The Butterfly Book. Doubleday, Page, & Company, $3.00.

HORNADAY, W. T. The American Natural History. Charles Scribner's Sons, $3.50.

HOWARD, L. O. The Insect Book. Doubleday, Page, & Company, $3.00.

HOWARD, L. O. Mosquitoes: How they Live, etc. McClure, Phillips, & Company, $1.50.

JORDAN AND EVERMANN. American Food and Game Fishes. Doubleday, Page, & Company, $4.00.

JORDAN, D. S. Manual of Vertebrate Animals of the Northern United States. A. C. McClurg & Company, $2.00.

JORDAN, D. S., AND KELLOGG, V. L. Animal Life. D. Appleton & Company, $1.25.

KELLOGG, V. L. Elementary Zoölogy. Henry Holt & Company, $1.20.

LUBBOCK, SIR JOHN. On the Senses, Instincts, and Intelligence of Animals. D. Appleton & Company, $1.75.

Lucas, F. A. Animals of the Past. McClure, Phillips, & Company, $2.00.

Miall, L. C. The Natural History of Aquatic Insects. The Macmillan Company, $1.75.

Morgan, C. L. Animal Behavior. Longmans, Green, & Company, $3.50.

Needham, J. G. Elementary Lessons in Zoölogy. American Book Company, $.90.

Parker, T. J. A Course of Instruction in Zoötomy. The Macmillan Company, $2.25.

Parker and Haswell. Text-book of Zoölogy. Two volumes. The Macmillan Company, $9.00.

Potts, Edward. Monograph of the Fresh-water Sponges. Obtainable from the author at 228 South Third Street, Philadelphia, Pa., $1.00.

Poulton, E. B. The Colors of Animals. D. Appleton & Company, $1.75.

Riley, C. V. Directions for Collecting and Preserving Insects. Smithsonian Institution, Washington, D.C., $.25.

Riverside Natural History. Six volumes. Houghton, Mifflin, & Company, $30.00.

Rogers, Mary Farrand. Life in an Aquarium. Leaflet No. 11, Nature Study Bureau, Ithaca, N.Y.

Semper, K. Animal Life as affected by the Natural Conditions of Existence. D. Appleton & Company, $2.00.

Stone, W., and Cram, W. E. American Animals. Doubleday, Page, & Company, $3.00.

Obtain from your senator or representative, Vols. 4, 6, 9, and 10, of the first session of the 47th Congress. These volumes contain illustrated articles on the whale, seal, etc. Also ask your congressman for the reports of the

United States Fish Commission. They contain much valuable and interesting information on the habits, life histories, and manner of catching many of the common food fishes.

The foregoing list of books will make a very good standard reference library for a high school. The books in the following list are of quite a different tone and are valuable in injecting an element into the work that will add interest, zest, and enthusiasm. Besides, they are good literature.

Bullen, Frank T. The Cruise of the Cachelot. Read it in connection with the study of the whales. D. Appleton & Company, $1.50.

Burroughs, John. Squirrels and Other Fur Bearers. Houghton, Mifflin, & Company, $1.00.

Comstock, A. B. Ways of the Six-footed. Ginn & Company, $.40.

Ingersoll, Ernest. Wild Neighbors. Harper & Bros., $1.50.

Long, William J. Wilderness Ways. Ginn & Company, $.60.

Roberts, Charles G. D. The Kindred of the Wild. L. C. Page & Company, $2.00.

Seton, Ernest Thompson. Wild Animals I Have Known. Charles Scribner's Sons, $2.00.

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